QUALITY INDICATORS FOR ROUGH RICE DURING AERATED STORAGE

by

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DISSERTATION

submitted in partial fulfillment of the

requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas
1985

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CHAPTER I

INTRODUCTION

Newly harvested rice generally has a moisture content between 18 and 24% (Schroeder and Calderwood, 1972). At that moisture, fungal growth is favored and grain damage results if the grain is held too long. Thus, newly harvested rice needs to be dried to a safe storage moisture. However, drying facilities, transportation and labor are oftentimes in short supply during the peak of harvest causing drying to be delayed. The usual practice is to hold the moist rice temporarily in aerated bins until dryers become available. During the holding process, rice and its associated microorganisms respire causing physical and chemical changes that result in weight loss, color change, off odor and other forms of deterioration (Milner et al., 1947a; 1947b; Christensen and Kaufmann, 1969; Milner and Geddes, 1954). The rate of deterioration is known to depend on grain moisture, temperature, degree of grain damage and the initial microbial load on the grain (Christensen and Kaufmann, 1974; Bottomley et al., 1950, 1952). Ultimately, the deterioration occurring during the holding of rough rice reduces the value of its milled products. Given the storage conditions and the condition of rough rice, it would be useful to have a mathematical model to predict changes in grain quality with storage time. To make that prediction, a reliable means to measure grain quality must be available.

Presently, the USDA quality grading of rice (1979) is based primarily on visual inspection, which is a subjective type of evaluation (Webb and Stermer, 1972). To provide a more reliable means of assessing rice quality, objective methods must be developed. Since most of the factors contributing to the lowering of rice quality are related to fungal invasion, the search for quality indices has been directed towards the biochemical changes related to fungal activity.

During respiration of fungi and grain, carbohydrates are degraded to carbon dioxide (CO_2), water and heat energy (Bottomley et al., 1950; Geddes, 1958). Measurement of the CO_2 evolved during respiration can be converted to the equivalent dry-matter loss (DML) based on the relationship that a one gram loss of hexose produces 1.47g of CO_2, 0.6g of water and 15.74 Joules of heat energy. Using DML as an index for grain deterioration, Saul and Steele (1966) reported that high moisture shelled maize could be held until a DML of 0.5%, beyond which the corn deteriorated to below U.S. No. 2 grade.

On the other hand, Seitz et al. (1982b) questioned the reliability of using DML as a grain quality indicator for maize. Those authors showed that the respiration of the grain itself was a major contributor to DML, and that ergosterol was a better index of fungal invasion than DML. They also found that after 0.5% DML fungal invasion in high-moisture corn varied considerably depending on the type of kernel damage and on the amount of intial inoculum. Furthermore, aflatoxin was produced in undamaged corn before 0.5% DML occurred, and the standard visual inspection used to grade maize did not reveal the fungal contamination in molded corn that had been handled in a stream of air (Seitz et al, 1982a).

In search for a better measure of fungal growth in grain, Seitz et al. (1977, 1979) suggested the possibility of using common fungal metabolites such as chitin and ergosterol. Those investigators demonstrated that ergosterol was a more sensitive measure of early fungal growth than chitin and showed that the ergosterol assay was easier and faster (1 h/run compared to 4-6 h/run). However, the Seitz and coworkers' method to determine ergosterol uses sophisticated chromatographic equipment that is not available in many developing countries. Furthermore, ergosterol in rice needs to be correlated with grading standards used to assess rice quality.

The objectives of this study were: (1) to establish a method for determining ergosterol content in grain using thin-layer chromatography (TLC) and ultraviolet (UV) spectroscopy; (2) to develop a regression equation relating DML or ergosterol in stored rough rice to its moisture content, storage temperature and amount of mechanically damaged kernels; and (3) to determine the validity of DML and ergosterol as deteriorative indices for rice.

CHAPTER II

REVIEW OF LITERATURE

Functional storage practices aim to maintain conditions in grain that will preserve its processing and marketing value at the highest level possible. However, grain starts deteriorating as soon as storage begins. The rate at which grain deteriorates depends on the storage variables, primarily its moisture and temperature (Hall, 1970), and on other factors including the degree of mechanical damage, impurities, the time after harvest and the initial inoculum load on the grain (Christensen and Kaufmann, 1974). All the above factors are related to fungal invasion as well.

FUNGAL GROWTH

Fungi grow over a wide range of environmental conditions. Generally, most fungi grow in a temperature range of 10^{o} to $40^{o}C$ with optima at 25^{o} to $30^{o}C$; a pH range of 4.5 to 8.0 with optima of 5.5 to 7.5, and at $a_w \geq 0.7$ (Deacon, 1980). Fungi primarily grow at their hyphal apices. Their growth is usually regulated by the rate of nutrient uptake and by the rate at which these nutrients are translocated to their apices. Fungi secrete enzymes onto substrates to break down large molecules into membrane-transportable units. In general, small molecules such as salts and minerals are transported by diffusion, while large molecules such as amino acids and sugars are transported via active transport mechanisms. Because fungal growth is directly related to extracellular enzymic activities and membrane transport mechanisms, it follows that the environmental factors that affect enzyme activity also affect fungal growth. Bernett (1976) reported that the kinetics of transporting nutrients in fungi is comparable to the kinetics of enzymic activity.

A typical fungal growth curve usually exhibits (a) a lag phase, (b) an exponential growth phase, (c) a stationary phase, and (d) a deceleration phase. The growth rate during the exponential phase, also known as the specific growth rate, varies with the fungal strain and the environmental conditions. The stationary and the deceleration phases occur as one or more of the nutrients or the environmental factors becomes growth-limiting.

RICE GRAIN FUNGI

Fungi that grow on rice can be classified on the basis of their ecology. Christensen and Kaufman (1982) classified grain fungi into either field or storage fungi. Field fungi invade grain kernels before grain is harvested or threshed. Generally, field fungi grow when the grain has an a_w >0.9. Thus, they usually do not survive in stored grain unless the grain is not mature when harvested or when wet harvesting conditions occur. Field fungi commonly found in rice include species of _Alternaria_, _Caldosporium_, _Fusarium_, _Helminthosporium_, _Curvularia_, and _Nigrospora_ (Schroeder and Calderwood, 1972). Usually, field fungi discolor the kernels, weaken the kernel structure, or kill the seed embryo resulting in shriveled kernels. Some species, such as _Fusarium roseum_, produce toxins (zearalenones) that are harmful to both humans and animals (Christensen and Kaufman, 1969; 1974).

In contrast to field fungi, storage fungi grow at a_w of 0.7-0.9 and at temperatures of -5^{o} to $55^{o}C$. Major storage fungi are species of Aspergillus and Pennicillium. In high moisture grain before drying, or in grain that become wet, Rhizopus, Mucor and Negrospora are common (Christensen and Kaufman, 1974). The predominant species identified in low moisture stored rice was Aspergillus glaucus, whereas A. flavus predominated in high moisture rice (Del Prado and Christensen, 1952; Schroeder and Calderwood, 1972).

Slow growing molds such as A. glaucus and A. restrictus generally account for the gradual increase in moisture content in rice stored at about 14% moisture. Those two molds increase grain moisture to provide a more favorable condition for the growth of other species. A. glaucus and A. restrictus may present problems in stored rice; the slow rate of heat evolved from their respiration sometimes cannot be detected by thermocouples used in sensing mold growth in stored grain.

Moderately to rapidly growing storage fungi, such as A. candidus, A. ochraceus, A. versicolor, A. flavus, A. parasiticus and Penicillium species are characterized by their relatively high moisture requirements (15-20% grain moisture content). A. candidus, A. flavus, and A. parasiticus were the species found mainly responsible for heating in stored grains (Christensen and Kaufman, 1974).

MEASUREMENTS TO PREDICT GRAIN QUALITY AND STORABILITY

Damaged Kernels. The USDA (1974) established general guidelines for quality inspection of rough rice. Rough rice is evaluated on the basis of grain size and shape, test weight per bushel, moisture content, odor, damage, heat-damage, milling yield and dockage. However, the final grade assigned to rough rice also depends on characteristics of the milled rice. Milled rice generally is downgraded by the presence of red rice, damaged kernels, heat damaged kernels, chalky kernels and musty or moldy odor. The damaged kernels are defined as "kernels and pieces of kernels of rice which are distinctly discolored or damaged by water, insect or any other means". The heat-damaged kernels are defined as "kernels and pieces of kernels of rice which are materially discolored, and kernels or pieces of kernels of parboiled rice in non-parboiled rice which are as dark as, or darker in color than, the interpretative line for heat-damaged kernels". According to Schroeder and Calderwood (1972) the 'damaged kernels' are the slightly discolored kernels and the 'heat-damaged kernels' are the dark amber to the brown colored kernels. The maximum number of heat-damaged kernels allowed in U.S. No.1 is three, U.S. No.2 is five and U.S. No.6 is 75 kernels in 500g milled rice sample. The maximum weight percentages of damaged kernels allowed are 0.5, 1.5 and 6.0% for rough rice to be in the above respective grades.

'Damaged' kernels are the most sensitive visual indicator of fungal damage. Using the present rice standard, rice is most likely to be downgraded due to the number of 'damaged' kernels in improperly stored rice. Visual inspection cannot detect the early stages of grain deterioration which precede the appearance of discoloration.

In attempts to develop early, reliable and convenient indices for grain deterioration, many biochemical tests have been studied. Since most of the factors contributing to the lowering of grain quality are related to fungal deterioration, the search for possible indices has been directed towards the biochemical changes related to fungal invasion. Some of the quality indices that have been studied include respiration, nonreducing sugars, fat acidity, chitin, fluorescence, and ergosterol (Pomeranz, 1982).

Respiration. Grain deterioration is related to respiration of both the grain and the accompanying microorganisms. Since it is generally assumed that carbohydrates are the main substrates utilized by both molds and grain during the respiration process, grain deterioration can be represented by the process of hexose (carbohydrate unit) oxidation as shown below;

$$C_6H_{12}O_6(s) + 6\ O_2(g) \text{------>} 6\ CO_2(g) + 6\ H_2O(l) + 2{,}833.4 \text{ Joules/g-mol}$$

In theory, one gram of hexose is converted to 1.47 g of CO_2, 0.6 g of H_2O and 15.74 Joules of heat.

Because CO_2 from respiration can be monitored throughout a storage period without disturbing the grain, many investigators have measured CO_2 and converted the CO_2 to dry matter loss (DML). DML has been proposed as an indicator of the extent of grain deterioration in corn (Bottomley et al., 1950, 1952; Christentensen et al., 1949; Saul and Steele, 1966; Steele et al., 1969; Seitz et al., 1982), wheat (Milner et al., 1947a; 1947b; White et al., 1982) and rough rice (Chikubu, 1970; Sukabdi, 1979; Tangonan and Jindal, 1982). Carbon dioxide evolved from samples (100-300g) has been quantitated using the Haldane-Henderson apparatus (Hummel et al., 1954; Milner et al., 1947a; 1947b; Bottomley et al., 1950, 1952), ascarite absorption columns (Saul and Steele, 1966; Steele et al., 1969; Sukabdi, 1979; Kalbasi-Ashtari et al., 1979; Tangonan and Jindal, 1982), and by infra-red absorption spectroscopy (Saul and Steele, 1966; Seitz et al., 1982).

Early investigators reported that CO_2 evolved during grain storage originated mainly from molds and negligibly from the seed itself (Oxley and Jones, 1944; Hummel et al., 1954). Oxley and Jones (1944) reported negligible change in respiration with the removal of the embryo of wheat. Thus, they stated that the respiration originated almost entirely from fungi in the grain's pericarp. There was no data given in their report.

Hummel et al. (1954) compared the respiration rates at 35°C of a surface disinfected wheat (1 % sodium hypochlorite for 1 min) and a mold-infected (inoculated with mold spores) western white wheat (Elgin). At 14.9-30.7% moisture, the respiration rates of the disinfected samples were low (1 to 265 mg/day from 100 g dry matter) and constant with time. Contrastingly, the mold-infected samples respired rapidly and exhibited a typical fungal growth curve. Those results suggested that CO_2 evolved during storage is primarily due to fungal growth.

Bottomley et al. (1950) studied the effect of environmental conditions on mold growth and on the biochemical changes in stored maize. They found that the water activity (a_w) of the grain had the greatest effect on DML. DML from maize stored 12 days at ~30°C and 0.75 a_w was 0.28%, and at ~1.0 a_w was 4.93%. Furthermore, DML increased with increasing temperature until a maximum was reached at 40°C. Beyond 40°C, DML was significantly decreased. However, a low correlation between mold count and DML was reported.

Saul and Steele (1966) correlated DML of slowly aerated maize (in-bin drying) with its change in quality grade. Field-shelled maize harvested at 28% moisture, which contained an average of 30% mechanically-damaged kernels, lost up to 0.5% dry matter during drying before its quality fell below U.S. No. 2 grade. This limit of 0.5% DML, which is widely used by engineers as a design criteria in grain drying, was determined with only three samples of maize containing 28-29% moisture and 26-32% mechanically-damaged kernels. To this writer's knowledge, no other data exists to support the recommendation for 0.5% limit.

In 1969, Steele et al. established a "multiplier" relationship between the permissible storage time and the variables of grain moisture, storage temperature and damage level of shelled corn based on 0.5% maximum permissible DML (Saul and Steele, 1966). The multiplier equation was possible because the shapes of the DML curves (DML<0.1%) with time were approximately the same for 275 samples out of 626 examined. The "multiplier" relationship is

$$T = Tr \times Mt \times Mm \times Md$$

where,

T = estimated allowable storage time to obtain 0.5 % dry matter loss

Tr = reference time = 230 h for corn having a 25% moisture content, 30 % mechanical damage and storage temperature of 15.6°C.

Mt, Mm, Md = multipliers for temperature, moisture, and mechanical damage, respectively, that are different from 15.6°C, 25% moisture, and 30% damage. The values of the multipliers can be obtained from charts provided in the reference.

In later investigations, Brooker and Duggal (1982) and Thompson (1972) used Steele's data (1967) to show that dry matter loss from maize at 15.6°C, 25% moisture and 30% damage could be expressed by

$$DML = 0.883[\mathrm{Exp}\ (0.006\ t) - 1] + 0.00102\ t$$

where,

DML = dry matter loss, %

t = storage time, h

Vemuganti (1980) developed an expression (KSUDML-MODEL) relating DML to moisture, temperature, time, and mechanically-damaged kernels. The KSUDML-MODEL was developed primarily from the graphical presentations and the experimental data of Steele et al. (1969). The relationship is

$$DML = 1 - \exp[-At^C \exp\{D(T-15.6) + E(W-0.14) + F(DAM)\}]$$

where,

DML = dry matter loss in decimal form

t = storage time, h/1,000

T = storage temperature, °C

W = grain moisture content on wet basis, decimal

DAM = mechanical damaged kernels, decimal

A, C, D, E and F = consatants of the equation

The KSUDML-MODEL has the following advantages over Steele's multiplier equation; (a) it can be used to calculate DML at a given moisture, temperature, mechanical damage level and storage time; and (b) it can be used in simulation computer programing to predict safe storage and drying times.

Sukabdi (1979) validated the KSUDML-MODEL with long (Lebonet) and medium (Brazos) rough rice. The equation described the DML of both rice well as indicated by the small standard error of DML (0.0004-0.0006) and the good T-values for the constants A, C, D and E. The mechanical damage variable in the equation was eliminated, since it was not assessed by Sukabdi. Values of the constants A, C, D and E, however, varied for each rice variety.

To study the effect of mechanical damage on DML in stored maize, Kalbasi-Ashtari et al. (1979) compared the respiration rates of hand-shelled maize, maize containing various amounts of visible mechanical damaged kernels, and mechanically-shelled "undamaged" maize. The mechanically-shelled "undamaged" maize which was determined by using microscropic examination (3x magnification), was selected from the mechanically-shelled maize lot. Different levels of damage ranging from 25 to 100% were prepared by mixing visibly damaged kernels with the hand-threshed maize. Respiration from 450g samples was monitored with time at 25°C and 25.5% moisture. The authors found that the respiration of the hand-shelled maize increased linearly with storage time, whereas that of the mechanically-shelled "undamaged" kernels increased exponentially with time. An increase in mechanical damage increased the level of DML linearly at 235 h. The amount of CO_2 evolved from the mechanically-shelled undamaged kernels at 235 h was about twice that of the hand-shelled kernels. The authors suggested that mechanical damage to kernels cannot be determined accurately by visual examination.

Seitz et al. (1982b) further evaluated respiration rates vs grain damage commonly incurred during the normal handling and processing operations of maize. Comparison of respiration rates were made at 29.4°C and 24% moisture on undamaged kernels (determined by microscopic examination), 100% brokens and fines, and on 57% artificially damaged maize kernels. Artificial damage on maize kernels was inflicted by: (1) cutting the germ, (2) slightly puncturing the germ, (3) cutting the backside of kernels, (4) cutting the dent region of kernels, and (5) impacting the kernels against a solid surface. Considerable variations in the respiration rates were observed after two days of storage among maize with different types of damage. The 100% brokens respired the fastest followed by those cut and slightly punctured at the germ. The dent cut had the lowest respiration rate among the types of damage studied. The respiration rate of the undamaged kernels was low and almost constant throughout the experiment. Type and location of kernel damage appreciably affects the respiration rate of stored maize.

To determine whether DML is an accurate quality indicator for maize, Seitz et al (1982b) also compared the respiration rates with ergosterol and aflatoxin contents of a hand-shelled disinfected (dipped in 5% sodium hypochlorite for 1 min) maize, undamaged white corn, and undamaged white corn inoculated with Aspergillus flavus spores with ergosterol and aflatoxin contents. The hand-shelled disinfected maize lost more than 0.5% DML at 24.9°C and 23.9% moisture without significant evidence of fungal growth. The undamaged white corn with and without *A. flavus* inoculation respired at relatively constant and almost equal rates, whereas their ergosterol and aflatoxin contents varied considerably. In those samples of maize, mold respiration contributed little to DML.

Relating DML to the U.S grade for rice, Sukabdi (1979) reported that the DML at which rice remained in good condition varied with grain moisture. A medium-grain rough rice (Brazos) at 22% moisture lost up to 0.25% DML at 29.4°C before falling below U.S. No. 2 grade, whereas a long-grain rice (Lebonet) at 18% moisture lost up to 0.5% DML at 29.4°C before falling below U.S. No. 2 grade. The amounts of the mechanically damaged kernels in both grains, however, were not reported.

More data on the validity of using DML as an indicator for quality deterioration in stored rice is needed. Sukabdi's results on DML *vs* quality of rice appear encouraging, but those of Seitz et al. (1982b) do not.

Fat Acidity. Grain lipases which are concentrated mostly at the outer layer of a grain kernel, catalyze the hydrolysis of triglycerides into free fatty acids and glycerol during storage. This change is generally accelerated by high moisture and warm temperatures, and even more so by an increase in molds which contain lipolytic enzymes on their hyphae. Thus fat acidity, reported as the milligrams of potassium hydroxide required to neutralize the free fatty acid from 100 g of grain (dry weight) has been proposed as an index for incipient grain deterioration

(Dirks et al., 1955; Hummel et al., 1954; Milner et al., 1945, 1947a, 1947b; Houston et al., 1957). However, Bottomley et al.(1950, 1952) found that fat acidity in maize stored at 19% moisture (a_w=0.8) and 30^{o}C increased very little as compared to mold count; but in samples stored at 31% moisture, fat acidity increased rapidly to a maximum at 4-6 days. Thereafter, fat acidity declined but mold population continued to increase until 12 days of storage. Thus, there was a poor correlation (r=0.2) between fat acidity and mold count. The authors attributed the low correlation to differences in the predominating microflora during storage, and their differences in utilizing free fatty acids as a carbon source. Hence, the decline in the free fatty acid observed in the growing mold population was attributed to the relatively fast rate of free fatty acid utilization as opposed to the molds' rate of free fatty acid release.

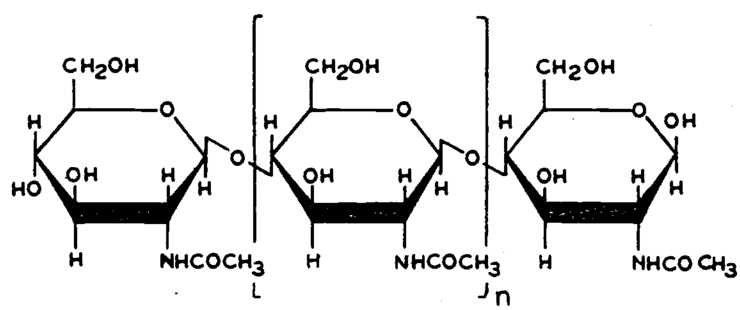
To study differences among molds in utilizing free fatty acids, sterilized defatted and fat-reconstituted defatted corn meals were inoculated with one of four species of fungi isolated from moldy stored maize (Goodman and Christensen, 1952). Those molds were *Penicillium solitum*, *Aspergillus flavus*, *Aspergillus candidus* and *Aspergillus amstelodami*. Both meals were conditioned to 20 and 30% moistures. The results agreed with those found earlier, that fat acidity sharply increased during the first period (4-6 days) of the experiment, and thereafter decreased in spite of continued mold growth. The maximum fat acidity values obtained in fat-reconstituted samples stored for 10 days with 20% moisture were 16.2, 16.8, 8.8 and 9.8 mg-KOH/10g for *P. solitum*,

A. flavus, A. candidus, and A. amstelodami respectively. In 30% moisture samples, fat acidity was raised to a maximum of 47.8 mg-KOH/10g in 10 days for P. solitum, 28.3 mg-KOH/10g in 15 days for A. flavus, and 49.2 mg-KOH/10g of the dry sample weight in 15 days for A. amstelodami. For the defatted samples, fat acidity values remained constantly low although approximately the same amount of fungal growth for both defatted and fat-reconstituted samples were noted. The authors attributed the above observation to the inherent differences among organisms to adapt to their environment and produce lipases in the presence of triglyceride substrates. It can be concluded that in an actual storage condition, where large numbers of different fungi are present, fat acidity does not necessarily reflect the fungal activity that may have occurred.

Pomeranz (1982) has also pointed out that there are other variables affecting fat acidity values. These include the method of analysis, the length of time involved in the extraction, the types and kinds of grain damage, the grain moisture content, and the ambient temperature during the extraction process.

Non-reducing Sugars. Non-reducing sugars as an index for fungal growth on grain is based on the assumption that invertase, an enzyme secreted by most storage fungi, is released when storage conditions favor microbial activities. The invertase catalyzes the hydrolysis of sucrose, which is the major non-reducing sugar in grain. Bottomley et al. (1950) found an inverse relationship between the logarithm of mold count and non-reducing sugar content of stored grain. Also, the non-reducing sugar content decreased linearly with an increase in a_w during storage. In a separate publication, Bottomley et al. (1952) reported large and inconsistent fluctuations in the relationship between non-reducing sugars and mold counts in stored maize. The authors attributed those variations to the differences among the predominating mold species in utilizing non-reducing sugars. Because grain also utilizes non-reducing sugar to maintain its viability, and the rate by which grain utilize sugars is activated by moisture and temperature, measurement of non-reducing sugar content in grain does not necessarily represent the true picture of the extent of grain deterioration.

Chitin. Chitin is a polymer of N-acetylglucosamine (see structure below), and is a constituent of fungal cell walls. Because deterioration



Chitin

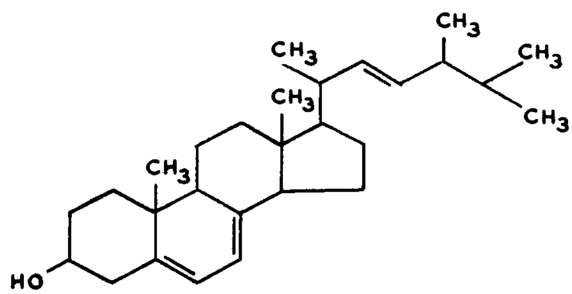
of stored grain has been equated to fungal growth in grain and because sound grain contains no chitin, the content of chitin has been suggested as a possible index for grain quality determination (Golubchuk et al.,1960; Donald and Mirocha, 1977; Nandi, 1978). All the above investigators found chitin measurement as a reliable index for fungal growth in grain. Seitz et al. (1979), however, showed that chitin was not sensitive enough to detect the growth of A. amstelodami. The exceedingly long time needed for the chitin assay (4 to 6 h/sample) has limited its use to test for grain quality.

Fluorescence of Mold Metabolites. The possibility of looking at fluorescence as an index of fungal invasion in grain had been suggested by many investigators (Cole and Milner, 1953; McDonald and Milner, 1954). Linko and Sogn (1960) found a good correlation (r=-0.95) between flourescence and seed germination. However, the correlation decreased to -0.41 when extreme points were not considered (Pomeranz, 1974). Sorger-Domenigg et al. (1955), on the other hand, found poor correlation (r=0.47) between fluorescence and germ damage in 68 samples of hard red spring and hard red winter wheat.

In 1970, Cooks et al. identified the fluorescence of mold metabolite as 4,6,8(14),22-ergostatetraene-3-one (ETO), a highly species dependent metabolite. The authors suggested that ETO might be useful in differentiating mold species. Comparing ETO with another fungal steroid (ergosterol), Seitz and Paukstelis (1977) found that ETO was a less sensitive index than ergosterol. ETO concentration for a 21-day Alternaria alternata culture was found to be 1.8 to 6.0 μg/g as compared to the 40 to 330 μg/g concentration of ergosterol.

Ergosterol. Ergosterol is the principal sterol in most fungi. It does not occur in significant amounts in higher plants, which makes ergosterol a sensitive measure of fungal invasion in stored grain. Furthermore, the presence of the conjugated double bonds in ergosterol at carbons 5-6 and

7-8 (see structure below) causes ergosterol to absorb UV-light strongly between 240-300 nm; other plant sterols absorb weakly at wavelengths greater than 240 nm.



Ergosterol

Seitz et al. (1977) developed a method to quantify ergosterol from the unsaponified lipid fraction of grain by high performance liquid chromatography (HPLC). In the event of unavailability of HPLC equipment, they suggested the use of a UV-spectroscopy method to quantitate ergosterol. Naewbanij et al. (1984) developed a TLC-UV method to quantify ergosterol. Using the TLC-UV method, they found ergosterol values obtained in rice, corn, and wheat in close agreement with those obtained by the HPLC method. The TLC-UV has good reproducibility and a sensitivity of 1 µg/g. On the other hand, the HPLC had a sensitivity of 0.05 µg/g.

Seitz et al. (1979) compared ergosterol and chitin assay for monitoring fungal growth in inoculated milled rice. They found that ergosterol was a more sensitive index to detect the early growth of fungi during storage than chitin. Ergosterol was detected ~24 h earlier than chitin in inoculated milled rice.

In later studies Seitz et al. (1982a, 1982b) showed that ergosterol was a more reliable measure of the extent of fungal invasion in high moisture maize than either dry-matter loss or the visual inspection used in the official grading procedure of the USDA.

CHAPTER III

ERGOSTEROL ASSAY BY THIN-LAYER CHROMATOGRAPHY AND ULTRAVIOLET SPECTROSCOPY

INTRODUCTION

In 1977, Seitz et al indicated that ergosterol is a sensitive measure of fungal invasion in grain. Ergosterol is the principal sterol in most fungi, but does not occur in significant amounts in higher plants. Furthermore, ergosterol is easily quantitated because of its ultraviolet (UV) absorption peaks at 282 and 293 nm and its different UV spectrum from other plant sterols. The conjugated double bonds in ergosterol at carbons 5-6 and 7-8 cause ergosterol to absorb UV light strongly between 240-300 nm, whereas other plant sterols absorb weakly at wavelengths greater than 240 nm.

Seitz and co-workers in 1977 developed an assay method to quantify ergosterol in the unsaponified lipid fraction of grain by high performance liquid chromatography (HPLC). At the same time they suggested that preparative thin-layer chromatography (TLC) and UV spectrophotometry could be used to estimate ergosterol if HPLC equipment was not available. The objective of this part of the research was to develop a TLC-UV method to measure the amount of ergosterol in grain. The work was a collaborative effort that involved Dr. Paul A. Seib and Ms. R. Burroughs, Department of Grain Science and Industry, Kansas State University; Dr. D.S. Chung, Department of Agricultural Engineering, Kansas State University; and Dr. L.M. Seitz, U.S. Grain Marketing Research Center, U.S. Department of Agriculture, Manhattan, KS. This work has appeared in Cereal Chemistry Vol. 61, No. 5, pp 385-388; 1984.

EXPERIMENTAL

Standard Curve. Ergosterol from Sigma Chemical Co., St. Louis, MO, was purified by crystallizing twice from absolute ethanol. The ergosterol used in the crystallization was purged 1 h with nitrogen (prepurified grade, Matheson Gas Products, Joliet, IL). The plate-like crystals were vacuum dried and had a melting point of 164^{o}C. Lamb et al (1946) reported a melting point of 162-7^{o}C.

A stock solution of ergosterol (1.5 mg/ml) was diluted with ethanol to obtain concentrations of 0.01, 0.02, 0.03, 0.04 and 0.05 mg/ml. Absorbances were read at λ_{max} 282 nm and 293 nm using a Beckman DB-G spectrophotometer (Beckman Instrument, Fullerton, CA).

HPLC assay for ergosterol was done by Dr. L.M. Seitz at the U.S. Grain Marketing Research Laboratory, USDA, Manhattan, Kansas. The assay was conducted using a 5 μm C_{18}-reverse-phase column (3.9 mm x 15 cm, Waters Association, Milford, MA) maintained at 50^{o}C. The mobile phase was 95% methanol moving at a flow rate of 1 ml/min. Components leaving the column were detected using UV at 282 nm; ergosterol eluted at 10.9 min. A standard curve was constructed by injecting 10 µl of each solution of the standard ergosterol prepared above. The concentration of ergosterol was plotted against the area under the curve of the eluted standard. An area integrator (Hewlett Packard, Model 1080B, Palo, Alto, CA) was used to calculate the area of the eluted standard.

Recovery of Ergosterol after TLC. Ergosterol (40-200 μg) was applied in a band to precoated TLC plates (20x20 cm, coating 250um thick, Brinkmann G-25HR, Brinkmann Instruments, Waterburg, NY). A second plate (2.5x20 cm) was spotted to determine the migrating distance of ergosterol. The two plates were developed together in benzene-acetonitrile (9:1, v/v) until the solvent reached the top of the plate. The small plate was sprayed with 50% H_2SO_4 and heated on a hot plate; ergosterol gave a gray-brown color with an R_f value of about 0.3. Immediately after development, the band of silica gel (~0.25 cm wide) containing ergosterol on the large plate was scraped off, and the silica gel extracted with 4.0 ml of oxygen-free absolute ethanol. The mixture was filtered by gentle suction through a coarse sintered-glass funnel, and the absorbance of the filtrate was read at 282 and 293 nm. A blank solution was prepared by extracting silica gel scraped from a plate that had not been streaked with ergosterol but had been developed in benzene-acetonitrile. The absorbance of the blank solution was 0.015-0.046 at 282-310 nm when read against absolute ethanol.

In a separate recovery experiment, the TLC plates were treated as described previously, but the developed plates were allowed to stand at room condition up to 14 h prior to scraping and extraction.

UV Spectra of Non-saponifiable Lipid Fraction Extracted from Rough Rice with and without TLC. Medium grain rough rice was harvested at 30% moisture at Beaumont, TX. The rice was sun-dried to 18% moisture and cleaned in a Carter dockage tester (Seedburo Equipment Co., Chicago, IL). Three sub-lots were treated as follows: sample A was further sun-dried to 13% moisture, and the dull and the damaged kernels were removed by hand;

sample B was also sun-dried to 13% moisture and had no further treatment; sample C was re-wetted to 20% moisture, stored at 35°C for 16 days and then air-dried to approximately 14% moisture. Duplicate subsamples of A, B and C, containing 50g of dry solid, were ground for 1 min in a high-speed grinder (Mitey-Mill, Model MX 228, Stur Dee Health Products, Island Park, NY). The non-saponifiable lipids were isolated as described by Seitz et al (1977).

Preparative TLC was used to purify the dry non-saponifiable lipid fractions from one sample set (A, B, C). Each residue (~25mg) was dissolved in 1.0 ml of benzene-acetonitrile (98:2, v/v) and an aliquot (250 µl) was streaked 50 ul at a time in a band 8cm long on the TLC plate. The plate was developed with benzene-acetonitrile (9:1, v/v), dried 2-3 min at room temperature and the sterol band located using a light box. The sterol band was visible as a well-resolved opaque streak at Rf ~0.3. Resolution of the sterol band was lost with sample sizes greater than 75g of rough rice. The silica gel containing the sterol band was scraped from the plate and extracted with the ethanol (4.0 ml). The UV spectrum of the solution was scanned between 276-310 nm. The fractions of the second set (A', B', C') were dissolved in ethanol, and the UV spectra recorded.

Recovery of Ergosterol from Rice, Wheat and Corn Spiked with Ergosterol. Rough rice (13% moisture) was harvested at 30% moisture in August, 1980, in Beaumont, TX, sun-dried and stored for 12 months at 5°C. Wheat (11.5% moisture) was a U.S. No. 1, hard red-winter variety harvested near Garden City, KS, in June of 1982 and stored for 3 months at 5°C. The corn

(14.6% moisture) was grown in eastern Kansas in 1980. Following harvest, corn was dried with ambient air held at 5°C for 23 months. Each grain was ground to pass through a U.S. No. 40 screen prior to use.

In the recovery experiment known quantities of ergosterol were added to duplicate samples (50g dry solid) using aliquots (100 to 400 µl) of a concentrated solution in ethanol (800 µg/ml). Ergosterol was added to the ground grain-methanol mixtures in the initial step of the assay procedure of Seitz et al (1977). The non-saponifiable residues were redissolved and chromatographed on thin-layer plates. Then the ergosterol band was extracted with ethanol (4.0 ml) as previously described. Quantitation of ergosterol in the ethanol solution was determined from absorbance at 282 nm corrected for the absorbance of interfering substances by subtracting the absorbance at 310 nm from that at 282 nm.

Ergosterol Assays by TLC-UV and HPLC. To compare ergosterol values obtained by the TLC-UV technique with measurement by HPLC, samples of rough rice, yellow dent corn and hard red-winter wheat with two levels of fungal invasion were assayed. Long-grain rough rice was obtained from one lot dried to 13% moisture immediately after harvest and from another which had been stored under controlled conditions (20% moisture, 35°C) for 15 days then dried to 13% moisture. Corn samples were from a lot of U.S. No. 2 (14.5% moisture) before and after storage at 25°C for 16 weeks with moisture adjusted to 16%. Prior to assay corn was dried to 14% moisture content. Hard red-winter wheat samples were obtained from U.S. No. 1 wheat (13% moisture). In one lot, 2% of the kernels were invaded by *Fusarium roseum*, and the other lot had 10% invaded (determined by incubating surface disinfected kernels on malt-salt (4% NaCl) agar).

Samples for ergosterol assay (300 g) were ground to about 60 mesh in an U-D cyclone sample mill (UD Corpporation, Boulder, Colorado) and were subdivided into four 50-g replicates. Two replicates of each sample were assayed using the TLC-UV technique, and the other two were quantified by HPLC. In the HPLC method, the dry non-saponifiable lipid fractions were dissolved in 2 ml methylene chloride:isopropanol (99:1, v/v), and 10 µl aliquots were injected.

RESULTS AND DISCUSSION

Standard Curve and Recovery after TLC-UV. Because ergosterol is susceptible to autoxidation and produces a cyclic hydroperoxide with low UV extinction at 282-293 nm (White et al, 1973), we first examined the recovery of ergosterol subjected to TLC on silica gel. The curves in Fig. 1 (p 31) show the recovery was quantitative (98%) when the TLC-UV procedure was carried out within 2 h. However, if the developed plates were allowed to stand exposed to air, recovery decreased. In one instance a developed plate stood 14 h at 25°C; the recovery of ergosterol was 29%.

UV Spectra of the Non-saponifiable Lipid Fraction Extracted from Rough Rice. The three samples analyzed were expected to contain amounts of ergosterol related to the degree of fungal invasion and growth (Seitz et al, 1979). Rough rice with kernels darkened by growth of field fungi contained more ergosterol than a sample with damaged and dull kernels removed (Fig. 2, p 32). Storage at 20% moisture and 35°C for 16 days resulted in extensive molding reflected in the high ergosterol content of sample C, which produced intense absorbance at 282 and 293 nm.

The three UV spectra provided the basis for the development of a TLC-UV method of assay for ergosterol. Ergosterol does not absorb at 310 nm (Seitz et al, 1977), but the sterol fraction from rice following the TLC purification absorbed somewhat at 310 nm due to interfering substances (Fig. 2). However, absorbance of the interfering substances in the sterol fraction was assumed constant between 278 and 310 nm (curves A, B, and C, Fig. 2); so subtraction of the absorbance at 310 nm from absorbance of the sterol fraction at 293 and 282 nm gave a measurement of ergosterol in the samples. Curves A', B' and C' in Fig. 2 show the need for TLC to purify the steroid fraction in the non-saponifiable lipids from rice. Without purification by TLC the absorbance of interfering substances (curve A' and B') increased dramatically at 293 and 282 nm.

Recovery of Ergosterol after Spiking. A spiking experiment determined that ergosterol could be recovered quantitatively after a combination of the following steps: (i) extraction of the lipids from the grain, (ii) saponification of the lipids, (iii) isolation of the non-saponifiable lipids and (iv) TLC purification. Recovery of ergosterol from rough rice with an initial ergosterol content of 1.3 $\pm$0.1 µg/g of dry solids ranged from 84 to 98 % for the four levels of added ergosterol. Fig. 3 (p 33) shows a linear response of recovered *vs* added ergosterol. When ergosterol was added to corn and wheat, recovery ranged from 91 to 102% and from 101 to 127%, respectively, and again levels in the grain samples increased linearly with added amounts (Fig. 3). The same correction for interfering substances was applied to absorbance readings for rice, corn and wheat.

Comparison of Ergosterol Assayed by TLC-UV and HPLC. Ergosterol values obtained by TLC-UV and HPLC (Table I, p 30) show that the TLC-UV technique has good repeatability ($\pm$0.49 µg/g) and give values in close agreement with HPLC determinations.

In the assay of hard red-winter wheat using the TLC-UV method, ergosterol content was calculated from the difference in absorbance at 293 and 310 nm. Ergosterol levels as much as 2 µg/g greater than the actual values (determined by HPLC) were found in some samples when the ergosterol was calculated from 282 nm absorbance readings. To test whether the absorbance reading obtained from the ethanol-extracted ergosterol band was attributed solely to ergosterol, the band scraped from the TLC plate was redissolved in 2 ml methanol, and a 30 µl aliquot was injected into the HPLC. The elution profile of this extract indicated unidentified interfering substances which were eluted at 6.4, 8.0 and 10.2 min; ergosterol was eluted at 10.9 min. Spectrophotometric scans (Fig. 4, p 34) of the three interfering substances using a photodiode ray detector (Hewlett Packard, Model 1040A, Palo Alto, CA), indicated that they absorb light between 250-290 nm. Similar interfering substances were present in negligible amounts in rice and corn regardless of the ergosterol level of the samples. The 101-127% recovery of ergosterol in spiked wheat samples reported in the preceding section resulted from the absorbtion by the interfering compounds at 282 nm.

The TLC-UV method is not as sensitive as the HPLC method of determining ergosterol. Seitz et al (1977) reported that the HPLC method could detect as little as 0.05 µg of ergosterol per gram of grain. The method described here can detect as low as 1 µg/g, which appears adequate to monitor fungal invasion in most grains during post-harvest holding, drying or storage. We found that rough rice, dried immediately after harvest to 13% moisture, contained 1.2-4.9 μg/g of ergosterol and that samples of hard red-winter wheat (U.S. No. 1) and of yellow dent corn (U.S. No. 2) contained 3.01-4.95 and 2.67-3.35 μg/g ergosterol, respectively. Seitz et al (1977) found 0.67-3.92 μg/g ergosterol in samples of freshly harvested Eagle wheat from three locations in Kansas over a three year period.

SUMMARY AND CONCLUSIONS

1. A TLC-UV method for quantitating ergosterol in wheat, maize and rice was developed.
2. Recovery of ergosterol from spiked grain samples was 84-98% for rough rice and 91-102% for corn. Delaying the extraction of the sterol band from the TLC plate for 2 h gave reduced recovery.
3. The TLC-UV method has a repeatability of (0.49 μg/g) and ergosterol values obtained were in close agreement with quantitation by HPLC.
4. The TLC-UV method can detect ergosterol content in grain at level as low as 1 μg/g.

Table I. Ergosterol Content in Rice, Corn and Wheat Obtained by TLC-UV and HPLC.

Sample	Ergosterol, ug/g[a]	
	TLC-UV[b]	HPLC
Rough rice		
Newly harvested	4.59	4.90
	4.90	5.02
Stored at 35 C, 20 %	10.29	10.34
M.C. for 15 days	11.91	13.71
Yellow dent corn (US No.2)		
As received	3.01	3.66
	3.33	3.68
Stored at 25 C, 16 %	13.64	12.52
M.C. for 16 weeks	13.65	13.98
Hard red winter wheat (US No.1)		
With 2 % Fusarium roseum	2.84[c]	2.70
	2.89[c]	2.78
With 10 % Fusarium roseum	3.22[c]	3.04
	3.35[c]	3.15
Standard deviation	$\pm$0.49	$\pm$1.06

[a] Two replicate sub-samples analyzed by each method.

[b] Values calculated from difference in absorbance at 282 nm and 310 nm.

[c] Values calculated from difference in absorbance at 293 nm and 310 nm.

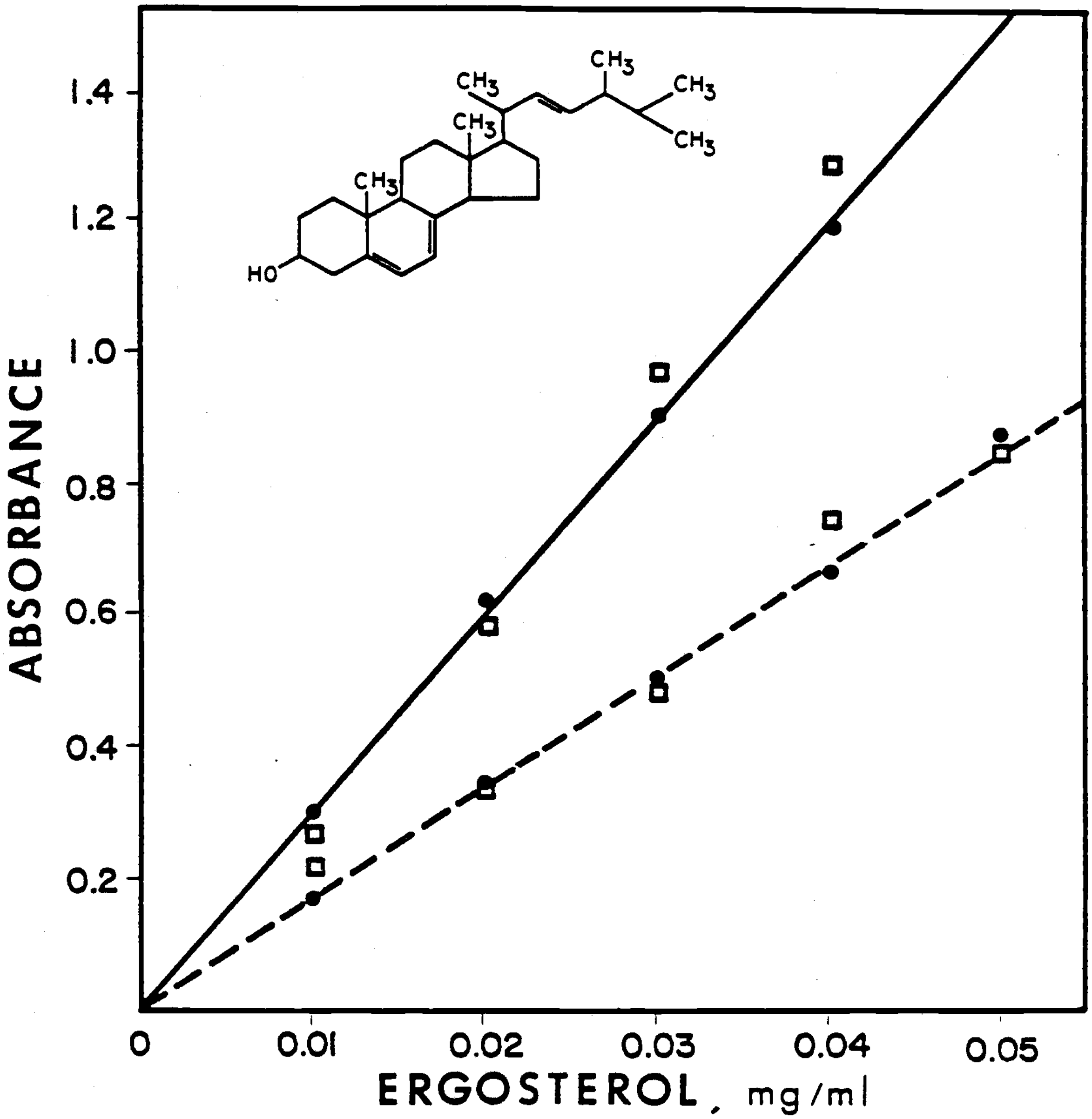


FIG. 1. STANDARD CURVE OF ERGOSTEROL DISSOLVED IN OXYGEN-FREE ETHANOL (●), AND RECOVERED AFTER TLC ON SILICA GEL PLATES (□) RECORDED AT 282 nm (—) AND AT 293 nm (- - -)

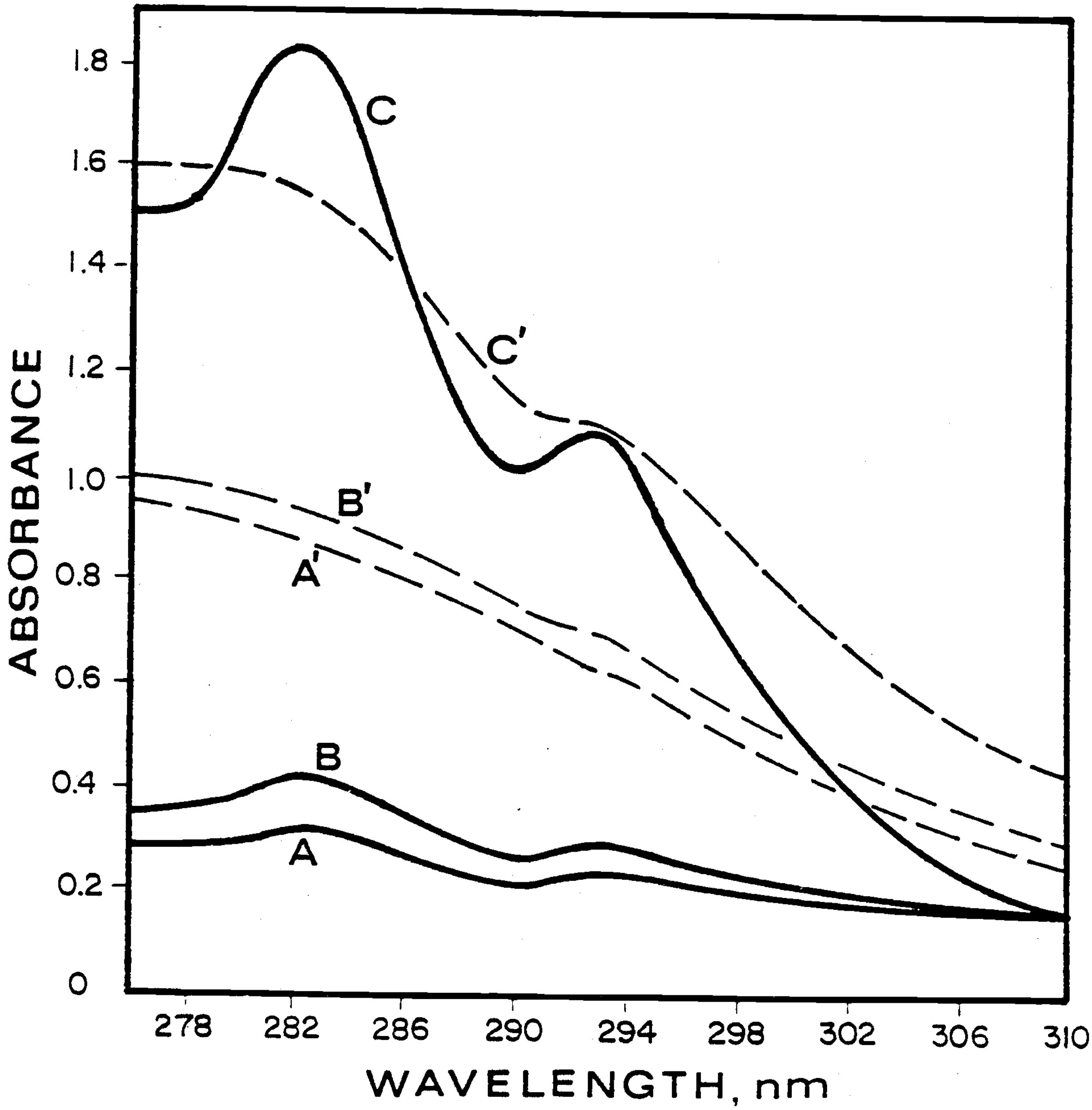


FIG. 2 . ULTRAVIOLET SPECTRA OF NON-SAPONIFIABLE LIPIDS OF ROUGH RICE BEFORE (-----) AND AFTER (———) TLC PURIFICATION

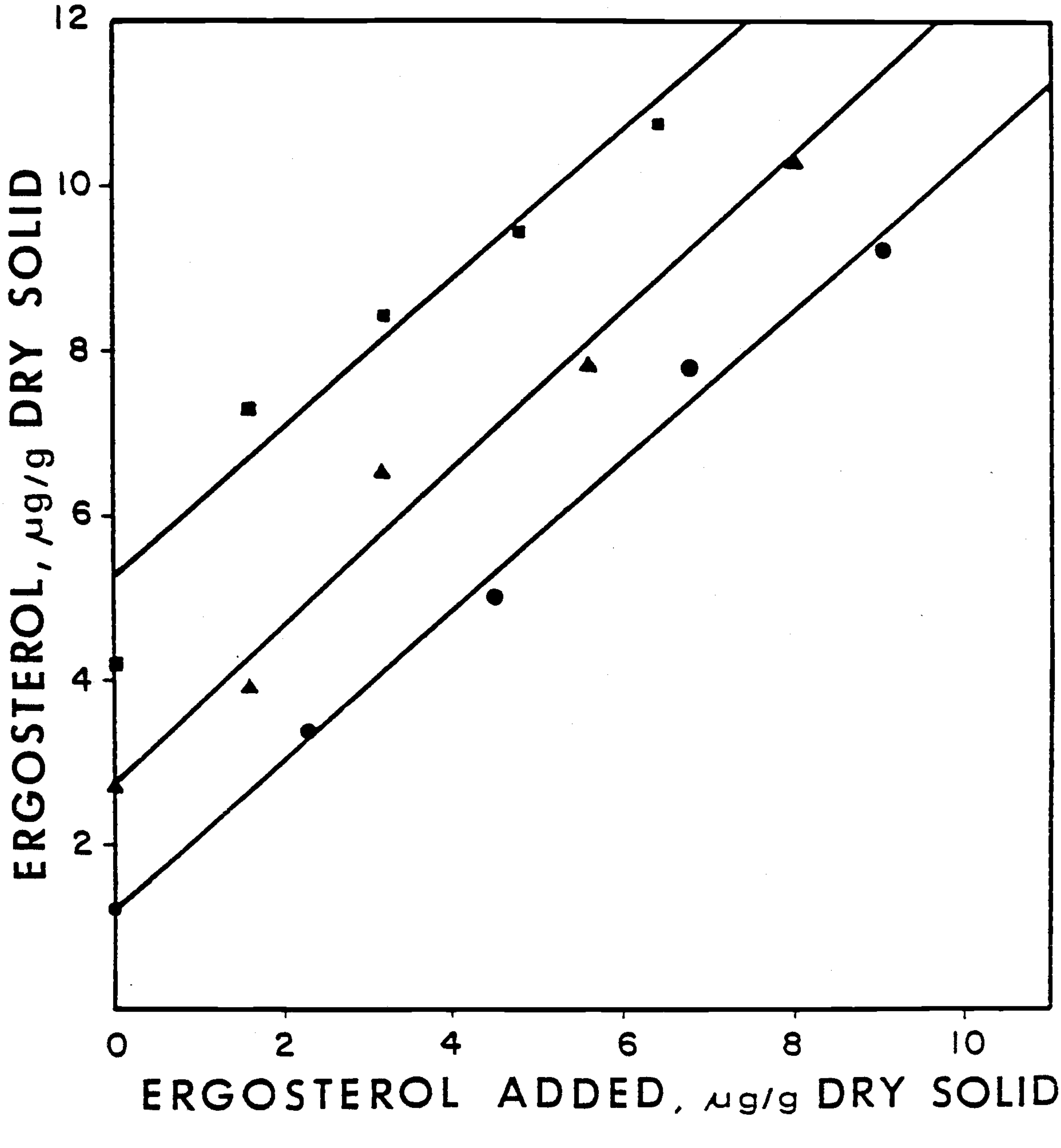


FIG. 3 . RECOVERY OF ERGOSTEROL ADDED TO RICE (●). CORN (▲) AND WHEAT (■)

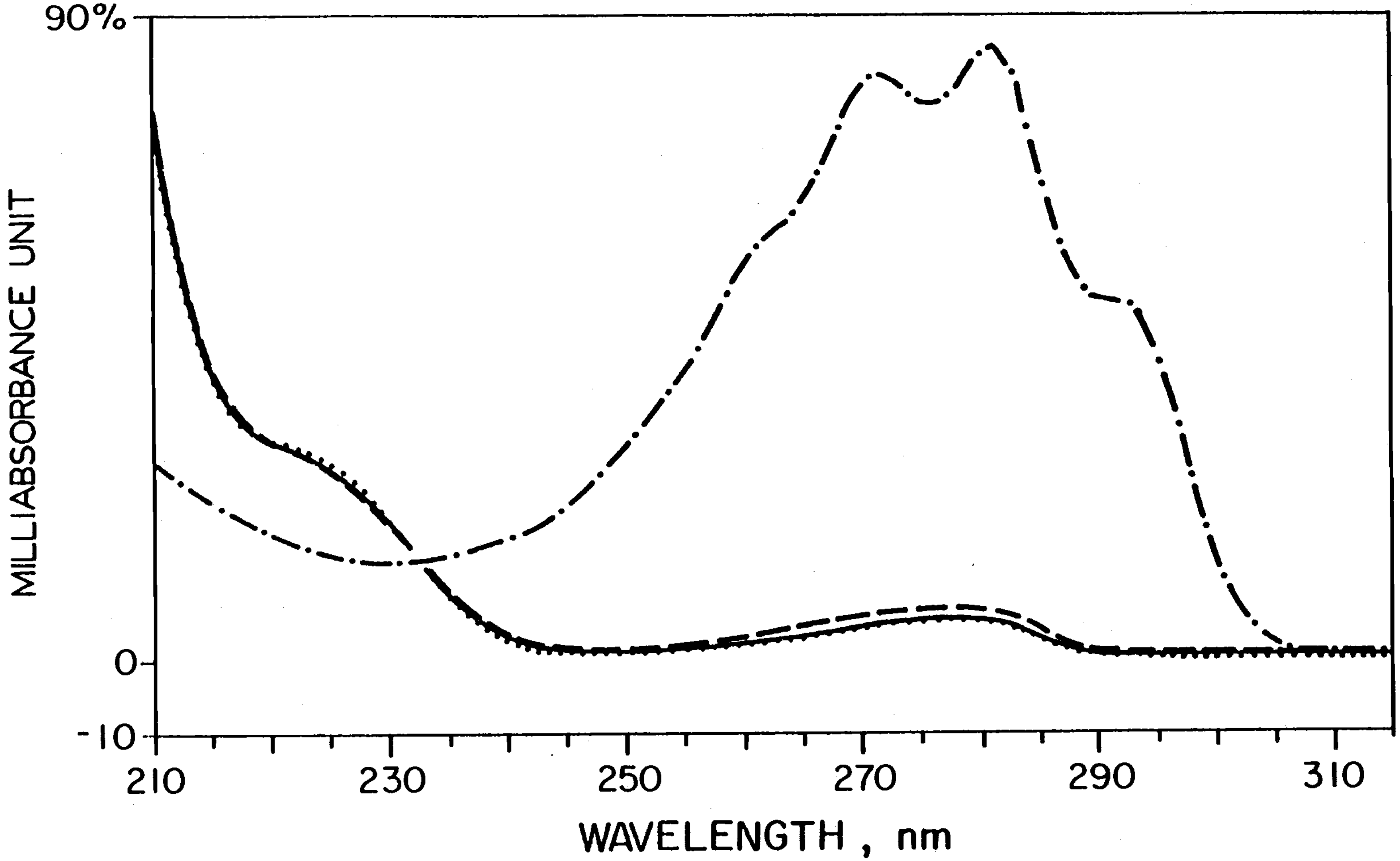


FIG. 4. SPECTROPHOTOMETRIC SCANS OF INTERFERING SUBSTANCES (——, ..., ----) AND ERGOSTEROL (—·—·—) AS ELUTED FROM THE HPLC COLUMN DURING ANALYSIS OF EXTRACTED ERGOSTEROL BAND FROM TLC PURIFICATION OF WHEAT CONTAINING 3.2 ug/g ERGOSTEROL

CHAPTER IV

DRY MATTER LOSS MODEL FOR ROUGH RICE

INTRODUCTION

Fungal invasion of grain perior to drying is the most frequent cause of economic loss in grain, during temporary storage; it ranks second to insect infestation during long-term storage. The potential for fungal deterioration of a given load of grain is governed mainly by four factors; (1) the moisture content of the grain, (2) the level of inoculum present on the grain, (3) the temperature of the grain, and (4) the level of mechanical damage suffered by grain during harvesting, threshing and handling.

Carbon dioxide evolved during storage has been used to measure the extent of fungal attack on grain in a laboratory set-up (Bottomley et al., 1951, 1952; Christensen et al., 1949; Hummel et al., 1954; Kalbasi-Ashtari et al., 1979; Milner et al., 1947a, 1947b; Saul and Steel, 1966; Seitz et al., 1982b; Steele et al., 1969; Sukabdi, 1979; Tangonan and Jindal, 1982) and in grain bins (Saul and Steele., 1966; Seitz et al., 1982a; White et al., 1982). The CO_2 evolved can be converted to dry-matter loss (DML) using the factor of 1.47g CO_2 per gram of dry matter lost. Saul and Steele (1966) reported that field-shelled maize failed to make U.S. No. 2 grade when the DML exceeded 0.5%. Monitoring CO_2 production from shelled maize at various moisture, temperature and mechanical damage levels and assuming the 0.5% DML limit, Steele et al. (1969) established a relationship between the maximum permissible storage time and the moisture, temperature, and mechanical damage levels for shelled maize.

Deterioration data determined on grain at constant moisture and temperature do not apply to all batches of grain, because moisture and temperature change due to respiration in the grain. However, if the temperature and moisture changes are slow compared to the rate of grade change in the grain, then a mathematical relationship of grade change with moisture, temperature and storage time can be useful. Such expressions have been used in computer simulation programs for grain stored under low aeration or static conditions (Thompson, 1972; Brooker and Duggal, 1982).

Dry-matter loss (DML) as an index of grade change caused by fungi has been criticized by Seitz and co-workers (1982a and 1982b). Those workers found that respiration of maize at high moisture is substantial compared to the respiration of fungi. However, Sukabdi (1979) reported some success in using DML to predict the U.S. grade of rice. He found that a medium-grain rough rice at 22% moisture lost up to 0.25% DML before falling below U.S. No. 2 grade, and a long-grain rough rice at 18% moisture lost up to 0.5% DML before falling below U.S. No. 2 grade. With the possibility that DML might be related to the grade of rough rice, this study was aimed at developing a mathematical model expressing DML in stored rough rice as a function of moisture, temperature, time, and mechanical damage level.

MATERIALS AND METHODS

Rice Samples. Long-grain (Newrex) and medium-grain (Nato) rice at 19 and

30% moisture (wet basis), respectively, were harvested using a combine in August, 1980 near Beaumont, Texas. Rice samples were shipped to Manhattan, Kansas in 100 lb cloth bags, around which dry ice was packed to maintain the samples below 20°C throughout the 24 h trip. Rice samples were stored temporarily at 5°C for 48 h, sun-dried to 18% moisture, cleaned with a small grain cleaner (Clipper M-28, Burrows Equipment Co., Chicago, IL.), and kept at -40°C until used in Experiments I and II.

For Experiment III, a new rice variety (007) developed at the Rice Experiment Station, University of Arkansas, Stuttgart, Arkansas was used. The 007 rice was harvested in July, 1982 at 17% moisture (wet basis). Depending on the harvesting procedure, rice 007 was obtained with two levels of mechanical damage. Rice with 1.6% mechanical damage was obtained by cutting with a sickle followed by hand-threshing. Rice 007 was obtained with 5.7% mechanical damage by mechanical harvesting followed by mechanical threshing. The level of mechanically damaged kernels was determined by visual inspection of triplicate 50g samples. Dehulled kernels, hull-damaged kernels and broken kernels were identified with the naked eye, separated by hand, and weighed on an analytical balance. The shipment, drying, and bagging of the 007 variety prior to freezing was the same as described previously for Newrex and Nato varieties.

<u>Experimental Apparatus for Measuring Carbon Dioxide Evolution</u>. The apparatus used to monitor CO_2 evolution from small amounts (~250g) of rice samples is shown in Fig. 1 (p 56). This system was described previously by Kalbasi-Ashtari et al. (1979) and is a modification of that developed by Steele et al. (1969). Steele et al. (1969) used a water bath to main-

tain sample storage temperature, whereas Kalbasi-Ashtari et al. (1979) used forced air.

The apparatus used in this study, located at the Agricultural Engineering Research Station, USDA, Ames, Iowa, consisted of (1) an air compressor; (2) an absorption column to remove atmospheric carbon dioxide; (3) a system to saturate air with water vapor; (4) a temperature-controlled storage chamber; (5) a sump and drying agents to remove water, and (6) an absorption system to trap respired CO_2 (Fig. 1). The storage chamber was equipped with a heating source (100 watts light bulb), a copper cooling coil, and a fan to circulate air. The cooling coil was preceded by a solinoid valve to control the flow of cold brine through the coil. The solinoid was controlled by a mercury thermoregulator.

The air compressor pumped atmospheric air through the stored grain at rate of 0.8 to 1.0 m^3/min-ton of sample. To ensure that the air flowing through the storage chamber was free of atmospheric CO_2, the air was passed through a CO_2 absorption column. This column was packed with small ceramic rings (raschig rings) to a height of about 18in, and potassium hydroxide solution (36% by weight) was continuously sprayed from the top of the column opposite to the air flow direction inside the column. The potassium hydroxide solution was changed twice a week during an experiment. Droplets of potassium hydroxide solution leaving the CO_2 absorption column were trapped by passing the air through a bottle of distilled water.

To ensure that the humidity of the air passing through the stored sample was in equilibrium with the a_w of the stored grain, air was saturated with water vapor by bubbling it through water whose temperature was controlled to $\pm 0.5^{o}C$. The temperature of water to saturate the air was predetermined so that the humidity of the air was in equilibrium with the a_w of the rice at a known moisture and temperature. The a_w of rice was calculated using the modified Chung-Pfost equation (1) for rough rice (Pfost et al., 1976).

$$Ln(a_w) = \frac{-594.61 \exp(-21.73\ M)}{(T + 35.70)} \qquad (1)$$

where,

a_w = water activity, decimal

M = moisture content on dry basis, decimal

T = temperature, ^{o}C

Saturated air of controlled temperature was forced through the rice in plastic jars inside the controlled-temperature ($\pm 0.5^{o}C$) chamber. Air flow in each sample jar was regulated by adjusting a screw clamp at the air-outlet valve for each sample jar. Measurement and adjustment of the air flow were done at 12 h intervals throughout the experiment. Condensate which collected in the sump at the exhaust of each sample jar was drained at the time of air flow measurement.

Exhaust air containing the CO_2 evolved from each sample was forced through a series of columns packed with silica gel, magnesium perchlorate, and ascarite (granular asbestos particles coated with sodium hydroxide). The silica gel column was periodically recharged with dry silica gel when about 60% of the column changed from a blue to a pink-brown color. The ascarite columns were weighed periodically (24 to 48 h intervals) on an analytical balance of ± 0.25 mg accuracy. An ascarite column was changed when the column weight increased 2%. Used silica gel was re-generated by drying in an oven, but used ascarite was discarded.

Evolution of Carbon Dioxide from Stored Rough Rice. The rice storage experiment was conducted as follows: Experiment I January-August, 1981; Experiment II January-August, 1982; Experiment III December, 1982 - March, 1983.

In Experiment I, approximately 150 lb of each of two rice varieties (Newrex and Nato) was removed from the freezer and placed in a cold room (5°C) for two weeks prior to shipping to Ames, Iowa. Table I (p 48) shows the condition of each rice variety prior to the storage experiment. Each lot was subdivided into two 75 lb sublots. One sublot of each variety was rewetted to 20 % moisture, and the remaining sublot of each variety was rewetted to 18 % moisture content. Grain moisture content was measured using an electronic moisture meter (Motomco Inc., Peterson, NY). Moisture adjustment in grain was done by adding a calculated amount of distilled water, mixing in a 100 gal rotating steel drum for 20 min, and then tempering 48 h. Mixing was repeated after 24 and 48 h of tempering.

Each mixed sublot was divided into 64 samples of 250g dry matter. Samples were randomly assigned equally into pairs of storage chambers maintained at 95°F (35°C), 85°F (29.4°C), 75°F (23.9°C), and 65°F (18.3°C). At each moisture level (18%, 20%) and storage temperature

(18.3^{o}, 23.9^{o}, 29.4^{o}, and $35^{o}C$), quadruplicate samples of rice were randomly removed from storage when DML of all remaining samples averaged ~0.13, 0.25, 0.30, and 0.50%. The storage experiment was terminated for each condition when about 0.5 % DML was observed. DML was calculated assuming that one gram of dry matter loss equaled 1.47 gram of CO_2 evolved. Sample weight, moisture content, DML and storage time were recorded at the time samples were removed from storage. Immediately upon removal from the storage chamber, samples were dried by spreading the grain ~1cm thick on a table top for a period of about four days. Dried samples (~13% moisture) were packed in Zip-loc plastic bags and transported to Manhattan, Kansas for grading and ergosterol assay. Prior to laboratory analyses, samples were stored at room temperature.

In Experiment II, the same quantity of rice (150 lbs) of both Newrex and Nato as was used in experiment I was removed from frozen storage and brought to room temperature in 48 h. To ensure that all samples were on the rewetting cycle of the equilibrium moisture curve, thawed rice was dried to 14 % moisture in a tray dryer (Aeroglide Corporation Machinery Manufacturers, Emporia, KS). Dried lots were stored in the cold room ($5^{o}C$) an additional two weeks before shipment to Ames, Iowa. Rice sublots were rewetted to 16 and 18 % moisture, and samples were stored and handled in the same manner described for Experiment I.

In Experiment III, the effect of mechanical damage on rice deterioration during storage was evaluated at $35^{o}C$ using 007 rice with two levels of mechanical damage and 20, 18, and 16% moisture. Hand-threshed 007 rice with 1.6% mechanical damaged kernels, and mechanically-threshed 007 with 5.3% mechanical damaged kernels were used (Table II, p 49). The two lots of rice were dried to 14%, stored in the cold for two weeks, then treated as the rice samples in Experiment I. To study the interaction between damage and temperature, sixteen additional samples of both damage levels were adjusted to 20% moisture, stored at 23.9°C, and CO_2 evolution measured with time as previously described.

RESULTS AND DISCUSSION

Moisture Changes in Grain During Storage. The final moisture content of the stored samples of rough rice was calculated from the difference in sample wet weight before and after storage, and was corrected for DML (Tables IIIa to Vb, Appendix A, pp 102-111). Eight out of 22 sample sets of Newrex and Nato rice, changed moisture during storage. About a one percent decrease in initial moisture was observed in five sets of samples stored at temperatures of 35° and 29.4°C. On the other hand, about a one to two percent point increase was observed in three sets of samples stored at 23.9° and 18.3°C. One set of Newrex rice sample stored at 23.9°C, however, gained 1.8% from its initial moisture of 18%, due to the lack of sensitivity of a temperature sensor that controled the water temperature of the air-humidifying unit.

Rice stored at 35° or 29.4°C, which was higher than room temperature (20°-24°C), was found to accumulate water sometimes in the exhaust air tubing. The condensate, which accumulated over a 4-5 h period, was great enough to block air flow from the sample jars. Air flow restriction from a sample jar probably caused respiration heat to build up within the sample because rough rice is a poor heat conductor. The increase in grain temperature lowered the relative humidity of the air within the sample, and ultimately lowered the moisture of the rice.

The increase in moisture observed in some samples stored below room temperature (23.9° and 18.3°C), may be attributed to the lack of a water-droplet trap in the air line leading from the air-humidifying bottle. Tiny droplets of water may have been carried with the water-saturated air into the stored samples. Water droplets were probably formed especially when the water level in the air-humidifying bottle rose due to water condensing out of the air supply. The air from the room was at 20°-24°C, and it was cooled as it passed through the cold water (17°-18°C) in the air-humidifying bottle. In fact, water droplets were sometimes observed in the air line supplying the sample jars. Periodic adjustment of the water level inside the humidifying bottle was necessary when the water level reached a distance of about 5 inches from the water-bottle outlet.

For samples stored at 16% initial moisture, no appreciable change in moisture content was observed. The a_w of 0.85, which corresponds to 16% moisture in rough rice, lies on a relatively flat portion of the rice isotherm curve (Chikubu, 1970), as compared to 0.92 and 0.96 a_w for 18 and 20% moisture rice. Thus, a slight deviation in relative humidity resulting from heat build-up had little influence on the resulting grain moisture content.

Overall, only a slight variation (usually $\pm$0.15-0.80%) in moisture within each set of samples was observed (see Tables IIIa to Vd, Appendix

A, pp 102-111). To account for experimental moisture variation, moisture levels were assigned the average overall final moisture of the samples taken out during storage.

Dry Matter Loss. The cumulative weight of CO_2 generated from each stored rice sample was converted to DML based on the relationship that one gram of hexose (dry matter) evolves 1.47 g of CO_2 during respiration. Tables VIa to VIId (Appendix B, pp 113-140) present the cumulative weights of CO_2 evolved and the average DML for Newrex and Nato rice stored at 35°, 29.4°, 23.9°, and 18.3°C and a final moisture ranging from 15.7 to 20% (Tables IIIa to IVd, Appendix A, pp 102-111). Tables VIIIa to VIIIh (Appendix B, pp 141-148) present the cumulative weights of CO_2 and the average DML for the hand- and the mechanically-threshed 007 rice stored at 35° and 23.9°C and a final moisture ranging from 15.4 to 20% (see Tables Va and Vb, Appendix A, pp 110-111).

The cumulative weight of CO_2 varied considerably among replicates in a set of samples held at a given moisture and temperature as might be expected in a biological experiment. However, some replicate samples, such as sample Nos. 104, 134, 222, and 228 in Table VI (see p 50), generated less CO_2 than the rest within the set. Those samples which appeared to generate abnormally low levels of CO_2 were eliminated from the experiment on the suspicion that a leak might have occurred along the exhaust air line from the test sample. Tables VIa to VIIIh (Appendix B, pp 113-148) present the samples that were used to determine DML and other grain quality factors. Overall, 340 out of 512 samples originally placed in the chambers provided data used in this work.

Mathematical equations were derived to express DML from rough rice in terms of time, moisture, temperature and mechanical damage to grain. The DML equation that was used previously by Sukabdi (1979) for rough rice was tried in this work to confirm its validity for rough rice.

KSUDML-MODEL presented in equation (3) was developed by Vemuganti (1980), and was tested by Sukabdi (1979) to fit the DML data for long-grain (Lebonet) and medium-grain (Brazos) rough rice. The equation relates DML to moisture, temperature, mechanical damage and storage time by assuming an exponential effect of moisture, temperature and mechanical damage on fungal growth.

$$DML = 1 - \exp[-At^{C}\exp\{D(T-15.6) + E(W-0.14) + F(DAM)\}] \qquad (3)$$

where,

DML = dry matter loss, decimal

t = storage time, h/1000

T = temperature, $^{\circ}C$

W = moisture content in wet basis, decimal

DAM = mechanical damage kernels, decimal

A, C, D, E and F = constants of the equation

To test whether the KSUDML-MODEL fit the experimental data, a non-linear-iteration (Statistical Analysis System (SAS), SAS Institute Inc., Cary, North Carolina) was used to find values of the constants. The mechanical damage component on the right side of the equation was omitted, since the DML data set for Newrex and Nato rice contained only one level of mechanically damaged kernels.

The coefficients of constants A, C, D and E for Newrex and Nato found in this work are compared to Sukabdi's constants found for Lebonet and Brazos in Tables IXa and IXb (pp 51-52). As can be seen in those Tables, the values for constants A, C, D and E in equation (3) derived in the present work varied from those obtained by Sukabdi for both long and medium grain rice. In addition, all of the constants were different for each grain variety. The difference in the values of the constants may be attributed, at least partly, to variety, damage, inoculum level, and foreign material differences between rice samples.

Typical plots of the observed and predicted DML curves using KSUDML-MODEL (Figs. 2 and 3, pp 57-58) showed that the KSUDML-MODEL fit the experimental data well. The relatively small residual standard error (0.0028-0.0031) for %DML and the non-significant different T-value (Table X, p 53) obtained between the observed and the predicted DML also verifies that the KSUDML-MODEL fit the experimental data.

To incorporate the mechanical damage variable into equation (3), a non-linear iteration procedure (SAS) was used to find the best fit values of constants A, C, D and E for the hand- and the mechanically-threshed rice 007. Values obtained for those constants (Table XI, p 54) show that except for constant E, all the constants were essentially equal for both the hand- and the mechanically-threshed 007 samples. Thus, only constant E varied with the degree of mechanical damage.

To verify the relationship of mechanical damage on the DML, equation (3) relating DML to the variables moisture, temperature, mechanical damage and time was used to fit the observed DML for 007 rice. The new values of constants A, C, D, E and the constant F were derived and are given in Table XII (p 55). The relatively high T-values for constants A, C, D, E and F, and the non-significant T-value for the observed and the predicted DML indicated that the KSUDML-MODEL adequately described the DML for rough rice (see Table XIII, p 55). Fig. 4 (p 59) showed the typical plot of the observed and the predicted DML using equation (3) and the constants in Table XII (p 55).

CONCLUSIONS

1. The general form of the equation to predict DML at various moisture, temperature, time, and mechanical damage levels is the same for all samples of rough rice.
2. The equation relating DML to the variables moisture, temperature and time is only applicable to a given variety of rice with defined levels of damage. The constants in the equation vary between rice samples.

Table I. Condition of Long Grain (Newrex) and Medium Grain (Nato) Rice Samples Prior to Storage

Property	Variety	
	Nato	Newrex
Dehulled kernels, %	0.70	2.32
Split hull on the kernel, %	6.42	11.30
Immature kernels, %	1.71	1.81
Germination, %[a]	80.00	40.00
Ergosterol content, ug/g[b]	2.82	2.45

[a] Average of four determinations; each germination test was made on a 25-kernel lot.

[b] Determined by the TLC-UV method.

Table II. Condition of Long Grain (Arkansas-007) Rough Rice Prior to Storage

Property	Threshing Method	
	Hand	Machine
Dehulled kernels, %	0.20	1.31
Split hull on the kernel, %	1.40	4.05
Immature kernels, %	3.06	0.79
Germination,[a] %	97.00	97.00
Ergosterol content,[b] ug/g	5.50	4.59

[a] Average of four determinations; each germination test was made on a 25-kernel lot

[b] Determined by the TLC-UV method

Table VI. Carbon Dioxide (Gram) Evolved by Long Grain (Newrex) Rough Rice During Storage at 19.5% moisture and 18.3° C.

Time (h)	Sample code																Ave.[a/] CO_2	DML[b/] (%)
	104[d/]	110	116	122	128	134[d/]	140	146	204	210	216	222[d/]	228[d/]	234	240	246		
49	0.004	0.070	0.068	0.065	0.084	0.024	0.055	0.160	0.099	0.114	0.106	0.037	0.020	0.096	0.093	0.122	0.094	0.026
100	0.054	0.159	0.127	0.130	0.176	0.066	0.099	0.306	0.166	0.232	0.191	0.056	0.028	0.193	0.172	0.253	0.183	0.050
140	0.062	0.238	0.184	0.190	0.268	0.084	0.131	0.468	0.236	0.355	0.280	0.072	0.034	0.297	0.207	0.375	0.269	0.073
167	0.071	0.176	0.213	0.217	0.313	0.102	0.156	0.544	0.272	0.417	0.322	0.083	0.042	0.349	0.280	0.458	0.310	0.084
236	0.155	0.388	0.382	0.445	0.576	0.197	0.303	0.934	0.495	0.788	0.562	0.246	0.100	0.685	0.502	0.920	0.582	0.158
289	-	0.620	0.475	0.558	0.730	0.239	0.384	c/	0.652	c/	0.762	0.329	-	0.783	0.666	1.235	0.686	0.187
355	-	0.802	0.589	0.703	0.944	0.286	0.458	-	0.796	-	0.937	0.364	-	0.997	0.790	1.562	0.857	0.233
404	-	0.872	0.684	0.787	1.138	0.324	0.513	-	0.925	-	1.078	0.398	-	1.140	0.910	1.792	0.984	0.268
428	-	1.057	0.726	0.817	1.236	0.346	0.536	-	0.989	-	1.142	0.423	-	1.202	0.942	1.892	1.056	0.287
476	-	c/	c/	0.917	1.426	0.409	0.603	-	c/	-	1.286	-	-	1.351	1.001	2.132	1.244	0.338
499	-	-	-	0.942	1.489	0.474	0.673	-	-	-	1.361	-	-	1.433	1.022	2.369	1.327	0.361
596	-	-	-	1.107	c/	-	0.984	-	-	-	c/	-	-	1.832	c/	2.990	1.728	0.470
643	-	-	-	1.184	-	-	1.284	-	-	-	-	-	-	2.177	-	3.544	2.047	0.557
668	-	-	-	1.210	-	-	1.363	-	-	-	-	-	-	2.288	-	3.687	2.137	0.581

a/ Average weight of carbon dioxide (g) evolved from 250 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

d/ Discarded sample.

Table IX a. Comparison of Coefficients of Constants A, C, D and E for Long Grain Rough Rice Obtained by Using the KSUDML-MODEL

Rice variety	Constant	Coefficient[a]	Confidence Interval (95%)		T-value
			Lower	Upper	
Newrex (present work)	A	0.00067	0.000597	0.000737	19.14
	C	1.42	1.342	1.497	36.18
	D	0.143	0.135	0.151	34.16
	E	38.66	36.37	40.88	33.91
Lebonet (Sukabdi, 1979)	A	0.001889	0.0018	0.00197	43.00
	C	0.710	0.693	0.728	79.30
	D	0.049	0.048	0.051	55.00
	E	31.62	31.0	32.2	99.50

[a] Obtained by non-linear-iteration procedure (SAS).

Table IXb. Comparison of Coefficients of Constants A, C, D and E for Medium Grain Rough Rice Obtained by Using the KSUDML-MODEL

Rice variety	Constant	Coefficient[a]	Confidence Interval (95%)		T-value
			Lower	Upper	
Nato (present work)	A	0.00031	0.00028	0.00034	18.18
	C	1.156	1.107	1.205	46.24
	D	0.125	0.120	0.131	43.53
	E	28.585	27.020	30.151	35.94
Brazos (Sukabdi, 1979)	A	0.00091	0.00088	0.00095	48.70
	C	0.6540	0.6430	0.6640	122.00
	D	0.068	0.067	0.068	120.10
	E	33.61	33.10	34.10	142.80

[a] Obtained by non-linear-iteration procedure (SAS).

Table X. Residual Standard Error[a] for DML(%) of Newrex and Nato Rough Rice

Rice Variety	Number of Observations	Mean Deviation	Standard Deviation	Minimum	Maximum	Standard Error of Mean	T-value
Newrex	151	-0.000721	0.034	-0.139	0.108	0.00276	0.216
Nato	310	-0.000690	0.055	-0.156	0.469	0.00314	0.220

[a] Computed from the residual value of the observed and the predicted DML using the KSUDML-MODEL (Vemuganti, 1980)

Table XI . Comparison of Coefficients A, C, D and E Obtained by Using the KSUDML-MODEL for the Hand- and Mechanically-Threshed Arkansas 007 Long Grain Rough Rice

Threshing Method	Constant	Coefficient[a]	Confidence Interval (95%)		T-value
			Lower	Upper	
Mechanical	A	0.0012	0.0010	0.0014	14.20
	C	1.170	1.103	1.237	36.56
	D	0.100	0.095	0.105	38.88
	E	31.841	30.036	33.646	36.48
Hand	A	0.00134	0.0012	0.0015	16.00
	C	1.083	1.021	1.144	36.09
	D	0.099	0.094	0.104	4.26
	E	14.451	13.081	15.822	21.48

[a] Obtained by non-linear-iteration procedure (SAS)

Table XII . Coefficients of Constants A, C, D, E and F Obtained by Using the KSUDML-MODEL for Arkansas 007 Long Grain Rough Rice Stored at ~16, 17 and 20% Moisture, 35^{o} and 23.9^{o}.

Constant	Coefficient[a]	Confidence Interval (95%)		T-value
		Lower	Upper	
A	0.00053	0.00045	0.00062	12.65
C	1.085	1.019	1.150	33.18
D	0.095	0.090	0.101	37.86
E	25.968	24.174	27.762	28.99
F	20.041	18.774	21.307	31.69

a As obtained from non-linear iteration prodedure (SAS)

Table XIII. Residual Standard Error[a] of DML (%) Obtained by Using the KSUDML-MODEL for Arkansas-007 Long Grain Rough Rice

No. of Observations	Mean Deviation	Standard Deviation	Minimum Value	Maximum Value	Standard Error of Mean	T-value
61	0.0015	0.0276	-0.041	0.079	0.0035	0.429

a Computed from the difference between the observed and the predicted DML

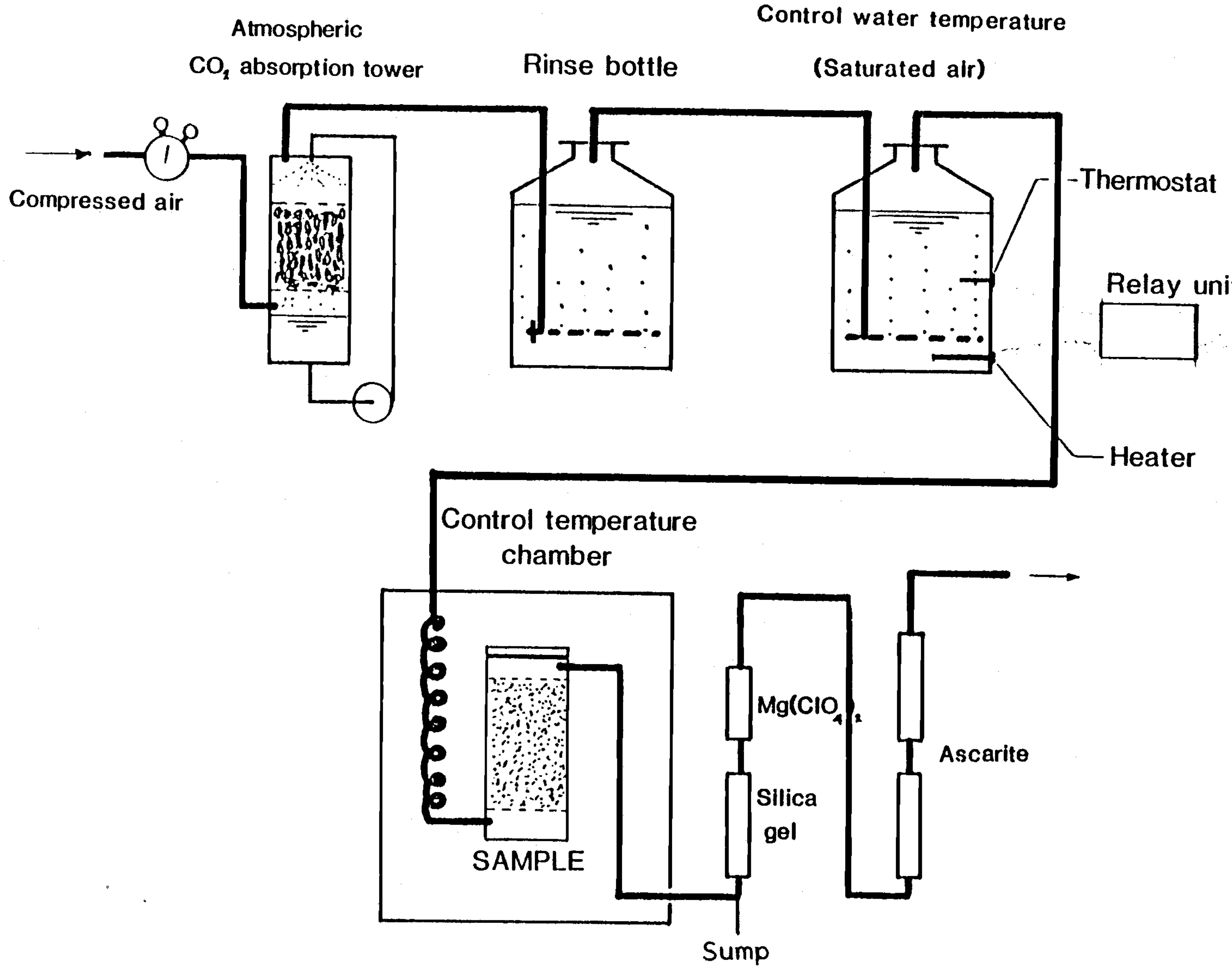


FIG. 1. CARBON DIOXIDE ABSORPTION SYSTEM

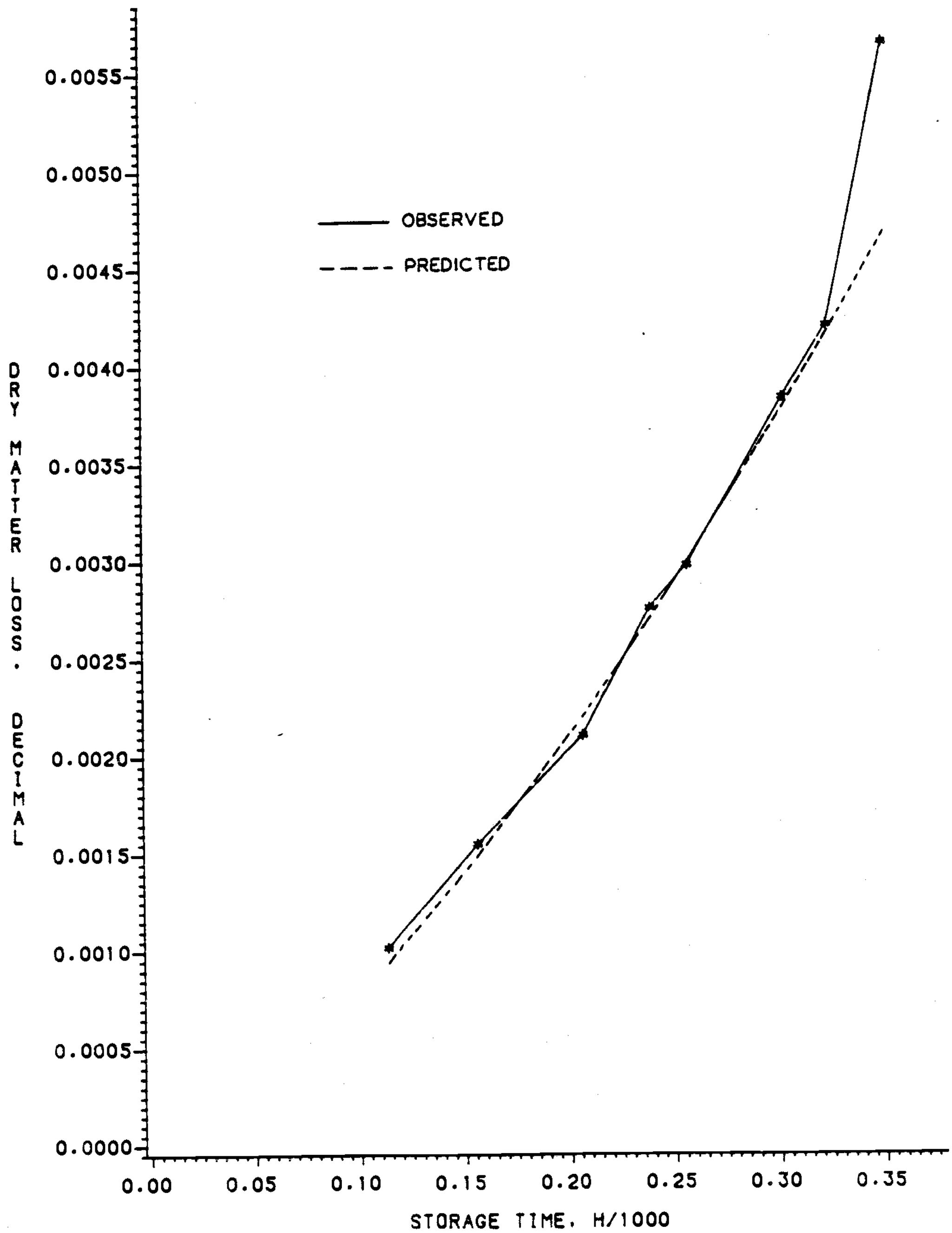


FIG. 2 . OBSERVED AND PREDICTED DML (USING THE KSUDML-MODEL) OF 'NEWREX' LONG GRAIN ROUGH RICE STORED AT 23.9 °C AND 19.3% MOISTURE

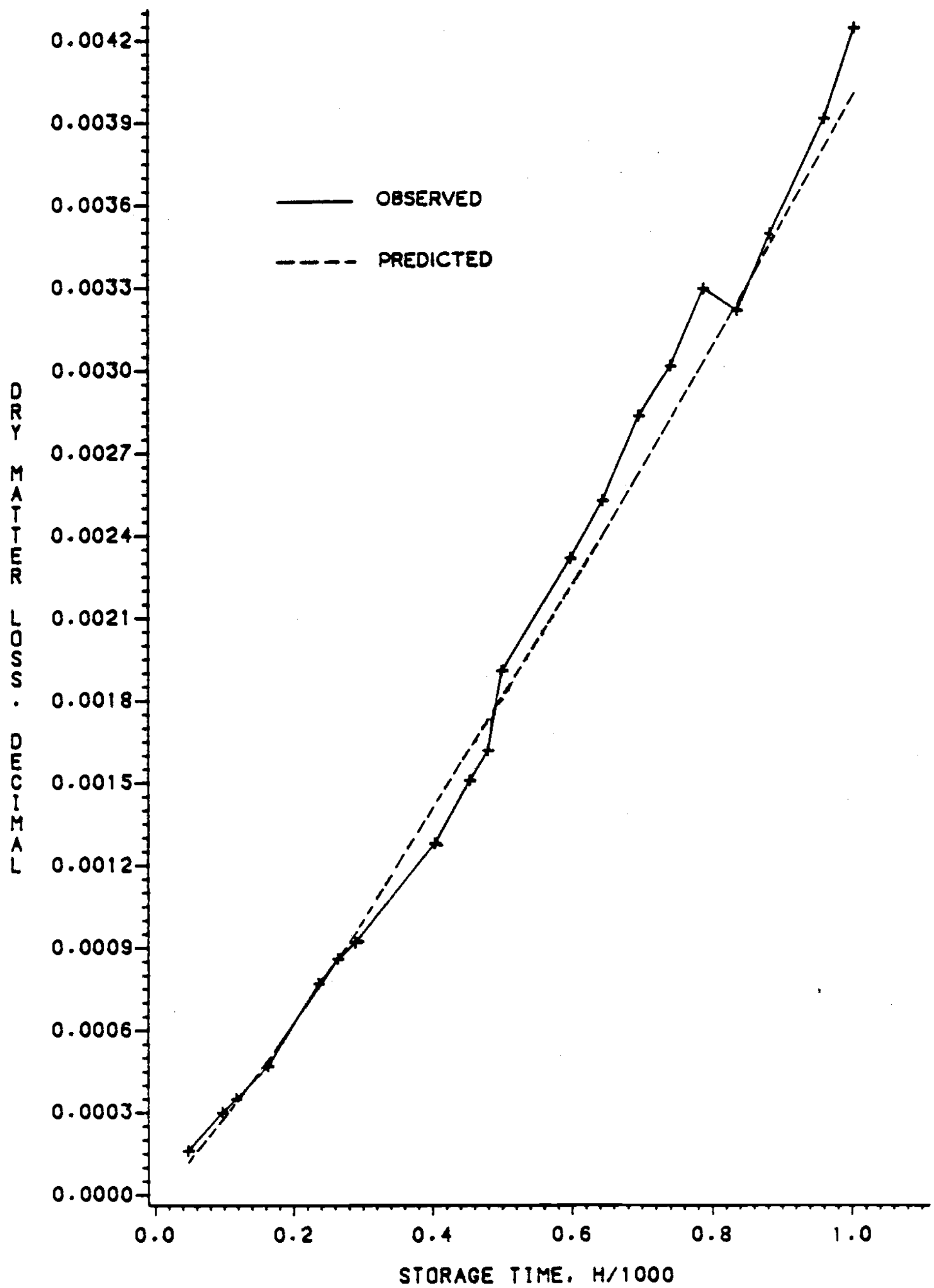


FIG. 3 . OBSERVED AND PREDICTED DML (USING THE KSUDML-MODEL) OF 'NATO' MEDIUM GRAIN ROUGH RICE STORED AT 23.9°C AND 19.3% MOISTURE

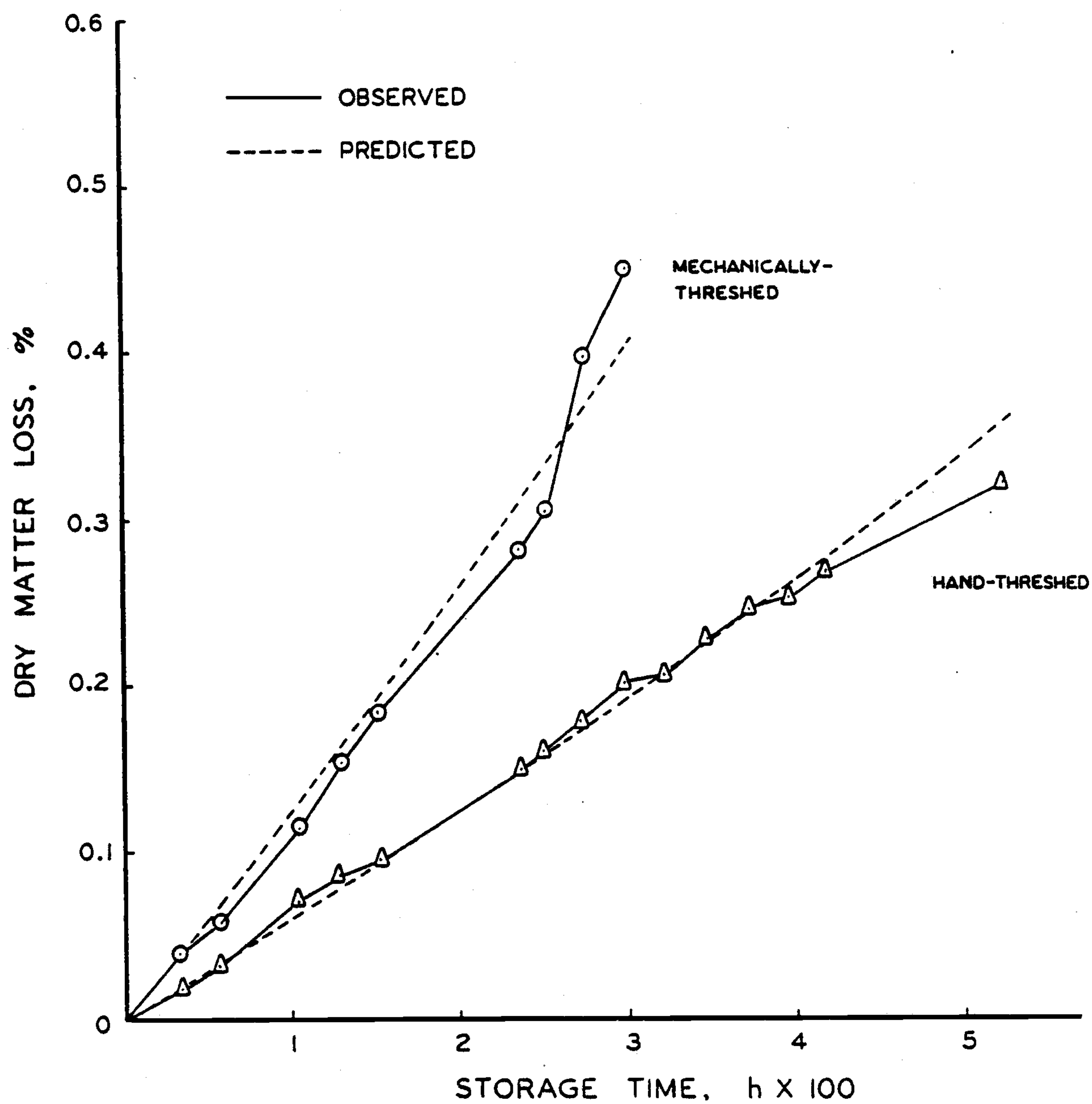


FIG. 4 . OBSERVED AND PREDICTED DML USING KSUDML-MODEL FOR ARKANSAS 007 LONG GRAIN ROUGH RICE STORED AT 23.9°C AND ~20% MOISTURE

CHAPTER V

RICE QUALITY INDICES

INTRODUCTION

The market price of rough rice in the United States and other rice producing countries depends on the type of rice and its quality. Quality factors include the presence of damaged kernels, grain size, shape, uniformity, milling yield, and the cleanliness of the grain. Of the above factors, the presence of damaged kernels, especially those that are discolored, is usually the first limiting factor in the grade of rice. The tolerable limit for damaged kernels set by the USDA Standard Grading System is 0.5, 1.5 and 2.5 weight % for U.S. Nos. 1, 2, and 3.

The discolored kernels among the damaged kernels are the slightly discolored (damaged) ones, and they are distinguished from the distinctly discolored (heat-damaged) kernels. Kernel discoloration is often a measure of fungal damage that has occurred in rice. During the milling of rice, attempts are made to remove discolored kernels and red rice. Red rice is a contaminating variety of rice with red pericarp. Both red rice and discolored kernels in milled rice are objectionable to consumers. Furthermore, rice that has been infected with fungi in the past but dried to a stable moisture contains a high level of fungal spores. If conditions become favorable for molding during holding or shipment of rice with large numbers of discolored kernels, such rice will deteriorate more rapidly than rice with few discolored kernels.

DML is currently used as an index of maize deterioration in dryer simulation models. Based on the data of Saul and Steele (1966) and Steele et al (1969), DML is predicted using a mathematical equation that has taken into account the variables moisture, temperature, time, and physical damage of the grain. It is generally assumed that shelled maize will drop below U.S. Grade No. 2 if DML exceeds 0.5%. The same relationship is used to predict safe storage time of high moisture maize (USDA, 1969; Thompson, 1972; Brooker and Duggal, 1982). The validity of using DML as an index of fungal invasion is still debatable. Seitz et al (1982) found in one sample of maize that the respiration of mold in stored maize contributed little to DML up to 0.5% DML of maize. Furthermore, those authors found that aflatoxin was produced in undamaged maize before 0.5% DML.

Two investigations relating DML with rice quality have been published. Sukabdi (1979) reported that the grade of rough rice at 22% moisture dropped below U.S. grade No. 2 when its DML exceeded 0.25%, whereas rice at 18% moisture fell below U.S. Grade No. 2 when its DML exceeded 0.5%. Tangonan and Jindal (1982), however, suggested 0.63% DML was the safe storage limit for a 25 to 30% moisture rough rice stored at 30°C. More information is needed on the relationship between DML and rice grade.

The use of ergosterol as a possible index for fungal invasion in grain was first suggested by Seitz et al (1977). In 1979 and 1982, those authors showed that ergosterol was a convenient, sensitive, and reliable measure of the extent of fungal invasion in maize, wheat and sorghum. However, ergosterol was not evaluated in rice, and its relationship to grain grade has not been explored.

To evaluate the use of DML and ergosterol as possible rice quality indicators, those indices were correlated to the percent damaged kernels, which is considered the most critical factor in grading of rough rice. With fungal invasion, the discolored kernels increase while the other types of damaged kernels probably remain the same.

MATERIALS AND METHODS

Samples of long grain (Newrex and 007) and medium grain (Nato) rice, which were stored at temperatures 35°, 29.4°, 23.9° and 18.3°C and moistures ranging from 15.7 to 20%, were used to follow ergosterol content and percent kernel discoloration. During storage of rough rice, quadruplicate samples (4 x 250 g) of stored Newrex, Nato, and 007 rice were randomly picked at each storage condition when DML averaged approximately 0.13, 0.25, 0.38, and 0.50%. The quadruplicate samples were pooled and further subdivided into two sub-lots for ergosterol assay and grading of the grain. Ergosterol and DML were correlated with the percentage discolored kernels.

Damaged Kernel Determination. After every storage experiment, the rough rice was dried to ~13% moisture in a thin layer at room conditions. Rough rice was husked using a rice sheller (McGill Inc., Houston, TX), and the brown rice was milled in a laboratory rice pearler (Satake Engineering Co. Inc., Tokyo, Japan). The mill was set to remove 12-14% by weight of the brown rice. The high degree of milling ensured that milled rice contained only discolored kernels to count for the damaged kernels. The other damaged kernels (insect, for example) ended up in the broken fraction of the milled rice.

Visual assessment of the percentage discolored kernels was made in duplicate 50 g samples of the milled rice. Discolored kernels were separated, weighed on an analytical balance, and were expressed as a percentage of the sample weight.

<u>Ergosterol</u> <u>Assay</u>. Duplicate 50 g samples of rough rice were ground 1 min in a high-speed grinder (Mitey-Mill model MX228, Sturdee Health, Island Park, NY), and the non-saponifiable lipid was extracted as described by Seitz et al, 1977 (see Fig. 1, p 81). Ergosterol was quantified using the TLC-UV method described in chapter III (pp 21-34).

RESULTS AND DISCUSSION

Tables Ia to IIc (pp 71-76) present the values obtained for DML, ergosterol content and percentage damaged kernels for Newrex and Nato rice stored at temperatures of 35°, 29.4°, 23.9°, and $18.3^{\circ}C$, and -16, 18 and 20% moistures. Values obtained for the hand- and the mechanically-threshed 007 rice samples are presented in Tables III and IV (p 77).

<u>Percentage</u> <u>Damaged</u> <u>Kernels</u> <u>vs</u> <u>Ergosterol</u> <u>Content</u>. Ergosterol is the total measure of field and storage fungi that invaded the grain. An increase in ergosterol content from its initial concentration, therefore indicates the level of fungal invasion in grain during storage. Fig. 2 (p 82) shows a high correlation (r=0.96) between the increase in ergosterol content in rough rice and the percent damaged kernels in the

milled rice for all samples of rough rice stored in the three experiments. The high correlation obtained between ergosterol content and the percentage damaged kernels indicated that fungal growth in the grain caused practically all discoloration in the stored rice. Ergosterol, therefore, is an accurate measure of rice quality changes during storage.

A linear-least-square extrapolation of the correlation plot indicates an increase of ~0.41 ug/g from the initial ergosterol content in rough rice before the kernel discoloration initiated. That result implies that ergosterol could, in theory, measure the early stage of fungal invasion that precedes the appearance of kernel discoloration. However, the variability of ergosterol content in rough rice limits the usefulness of ergosterol in detecting that early fungal growth in rough rice during storage. The regression line in Fig. 2 (p 81) shows that ergosterol concentration in stored rice increased by 0.41 ug/g dry weight of rice for every 1% increase in damaged kernels. For rice to have a U.S. No. 1 or U.S. No. 2 grade, the USDA requires that the present damaged kernels must not exceed 0.5 or 1.5%. Since the TLC-UV method used in determining ergosterol in stored rice has the standard deviation of $\pm$0.49 ug/g (Chapter III, pp 21-34), an increase of 0.41 ug/g ergoste rol, corresponding to a down grading of U.S. No. 1 to U.S. No. 2, cannot be determined accurately. However, an increase of >1 ug/g from the initial ergosterol value indicates a drop of rice quality below the U.S. No. 2 grade. In grains where grading is not as sensitive to discolored kernels and where the grain kernels are not white like milled rice, ergosterol would be an accurate index to predict loss of quality over DML (see next section).

Percentage Damaged Kernels vs. DML. Figs. 3 to 6 (pp 83-86) show scattered patterns of data points when the percentage damaged kernels are plotted against DML. Significant ($P<0.01$) but only moderate correlation ($r=0.62-0.64$) was obtained between the percent damaged kernels and the DML for all rice varieties, except for the hand-threshed-007 rice which had a high coefficient of correlation ($r=0.97$).

The relatively low coefficient of correlation observed between the percent damaged kernels and DML is apparently due to difference in the relative rates of grain and mold respirations as storage conditions vary. For example, at the same DML in the mechanically-threshed (Newrex, Nato and 007) grain, the grain stored at 18 to 20% moisture contained more damaged kernels than those same samples stored at 16% moisture. Thus, the relative rate of mold respiration to grain respiration was higher at 18 to 20% moistures. In contrast, ergosterol is not affected by grain respiration, and ergosterol concentration in grain correlated well with the percentage damaged kernels.

Differences in the percentage damaged kernels were observed between a hand-threshed rice and a mechanically-threshed rice stored under the same storage conditions. As expected, the hand-threshed (1.6% mechanical damage) had a lower rate of increase in the percentage discolored kernels than the mechanically-threshed sample (5.3-13.4% mechanical damage). The pericarp layer is known to protect the rice kernel against the penetration of oxygen, moisture, and microorganisms (Juliano, 1976; Bechtel and Pomeranz, 1978). Mechanical damage increases the susceptibility of rice to fungal attack by allowing fungal mycelia to penetrate through the injury in the pericarp to acquire nutrients. In the undamaged kernel, the intact pericarp resists mycelial penetration into the endosperm, thus limiting fungal growth on the kernel. In this work, fungal mycelia growing in the junction between lemma and palea were observed at 0.1-0.3% DML in the mechanically-threshed samples, whereas fungal growth at the germ end was observed at 0.3-0.7% DML in the hand-threshed samples.

The high coefficient of correlation (r=0.97) between the percentage discolored kernels and DML for the hand-threshed rice differed from the poor correlation between DML and the percent discolored kernels in mechanically-threshed rice. A linear relationship between DML and storage time was found for the hand-threshed rice (see Fig. 4, Chapter IV, pp 59), which indicates a constant respiration rate characteristic of grain respiration (Seitz et al, 1982b). The generally low percentage of discolored kernels obtained from the hand-threshed samples even at high moisture (20%) may have caused the number of damaged kernels to be within a narrow range at the various levels of DML, which apparently resulted in a good relationship.

<u>Ergosterol Model</u>. Because ergosterol correlates highly (r=0.96) with the percent discolored kernels in rice, and an increase in ergosterol content of 1 µg/g from its initial value can be used as the limit for rough rice before dropping below the U.S. No. 2 grade, ergosterol, therefore, can be used as a criteria for determining the maximum allowable storage time for rough rice at different moisture and temperature levels. An attempt was made to develop a regression equation that could describe the relation-

ship between ergosterol content and the variables of moisture, temperature and storage time. Such an equation could be used to predict the safe storage and holding time for high moisture rice.

In general, fungal growth rate is directly proportional to its size, or fungi grow exponentially with time (Trinci, 1974, 1976). Since ergosterol is a measure of the amount of fungal invasion in grain, it therefore follows that ergosterol should increase parallely with mold growth. Figs. 7 and 8 (pp 87-88) show the typical linear relationship between ergosterol content and storage time on a semi-logarithm scale for Newrex and Nato rice. The relationship is expressed mathematically as,

$$\mathrm{Ln}\left[\frac{\mathrm{ERG}}{\mathrm{ERG}_O}\right] = Kt \qquad (4)$$

where,

ERG = ergosterol content, µg/g

ERG_O = initial ergosterol concentration, µg/g

t = storage time, day

K = growth rate constant, day^{-1}

Using graphical evaluation of the growth rate constant (K) in relation to the moisture variable (Fig. 9, p 89), a parallel increase in K-values with the moisture levels on the semi-logarithm scale for each temperature was observed. Plotting the values of intercept obtained in Fig. 9 with the temperature variable (Fig. 10, p 90), the relationship (5) between K and the variables moisture and temperature was derived.

$$K = A \exp\{B(T) + C(M)\} \qquad (5)$$

where,

T = temperature, ^{O}C

M = moisture content on wet basis, %

A, B and C = constants

Substituting the expression (5) for K into equation (4), resulted in equation (6),

$$\mathrm{Ln}\left[\frac{ERG}{ERG_o}\right] = At\ \exp\{B(T) + C(M)\} \qquad (6)$$

A non-linear procedure (Statistical Analysis System (SAS), SAS Institute Inc., Cary, North Carolina) was used to find the values of constants A, B and C (Table V, p 78) in equation (6) for Newrex and Nato rice.

Equation (6) described well the increase in ergosterol content of Newrex and Nato rice during storage at a given temperature (35^o, 29.4^o, 23.9^o and 35^{o}C) and a given moisture (~16, 18 and 20%). The theoretical curves gave small residual standard errors (0.39-0.18), and the predicted ergosterol values were practically the same with the observed ergosterol values (Table VI, p 79), as indicated by the non-significant level of the T-statistics. The typical superimposed plot of the observed and the predicted are shown in Figs. 11 and 12 (pp 91-92) for Newrex and Nato rice.

T-Statistic tests for equality of the constants A, B and C (equation 6) as obtained from Newrex and Nato rice (Table V, p 78) showed that all the constants were different for the two rices. The differences in values of the constants may be attributed to the mechanical damage level as well as to grain differences.

An attempt to evaluate the effect of the mechanical damage term in equation (6) was unsuccessful. The limitted ergosterol data obtained from Arkansas 007 rice stored at 20 and 17% moisture, 35° and 23.9°C temperatures, at two levels of damage (1.6% for hand- and 5.3% for mechanically-threshed) was insufficient to obtain a significant level of the constants (Table VII p 80) in equation (6). The high level of immature kernels (~3%) for the hand-threshed Arkansas-007 rice may have caused variation in the initial ergosterol levels.

The empirical equation (6) developed in this work may be used to predict safe storage and holding time for long and medium grain rough rice at various moisture, temperature levels and at the mechanical damage levels defined in this experiment. A 1 µg/g increase from the initial ergosterol content may be used as a criteria for maximum permissible storage time for rough rice before dropping below U.S. No. 2 grade. Fig. 13 (pp 93) show the maximum holding or storage time for Newrex and Nato rice computed by using equation (6) and the above criteria.

SUMMARY AND CONCLUSIONS

1. Ergosterol correlated highly with the percent damaged kernels in stored rough rice. An increase in ergosterol content of >1 µg/g from its initial value would indicate the drop in quality of rice below U.S. No. 2 grade.
2. The percentage discolored kernels correlated poorly with DML from mechanically-threshed rice. Rice grade could not be predicted from DML.

3. One sample of hand-harvested and hand-threshed rice held at high moisture gave much less DML and ergosterol than did the mechanically harvested and threshed rice.
4. A mathematical equation relating ergosterol to the variables moisture, temperature and time was derived for stored rough rice. It is proposed that such an equation be used to model drying and holding of grain.

Table Ia. Ergosterol Content, Dry Matter Loss and Discolored Kernels in Long Grain (Newrex) Rough Rice Stored at ~20% Moisture.

Temperature (^{o}C)	Moisture (%)	Storage time, h	Dry matter[a] loss, %	Ergosterol[b] µg/g	Discolored[c] kernels, %
35.0	19.9	43	0.253	10.81	8.46
35.0	19.9	66	0.325	16.30	26.60
35.0	19.9	89	0.340	22.03	42.50
35.0	19.9	114	0.525	25.22	57.27
29.4	20.0	108	0.157	4.69	10.10
29.4	20.0	181	0.367	8.38	21.00
29.4	20.0	226	0.644	12.01	28.96
18.3	19.5	236	0.234	7.02	9.45
18.3	19.5	428	0.251	11.86	20.79
18.3	19.5	499	0.351	13.50	25.21
18.3	19.5	668	0.581	18.62	38.72

[a] Determined from the CO_2 evolved during storage.

[b] Assayed by TLC-UV technique.

[c] Determined by the percentage of discolored kernels per 50g sample.

Table Ib. Ergosterol Content, Dry Matter Loss and Discolored Kernels in Long Grain (Newrex) Rough Rice Stored at ~18% Moisture.

Temperature (°C)	Moisture (%)	Storage time, h	Dry matter[a] loss, %	Ergosterol[b] ug/g	Discolored[c] kernels, %
35.0	17.07	136	0.155	9.89	17.01
35.0	17.07	179	0.361	11.45	21.50
35.0	17.07	228	0.510	14.80	27.40
29.4	18.40	179	0.167	11.36	16.50
29.4	18.40	228	0.372	14.42	22.61
29.4	18.40	275	0.505	16.05	33.73
23.9	19.35	206	0.191	7.60	8.10
23.9	19.35	283	0.276	8.50	12.02
23.9	19.35	323	0.352	10.90	18.04
23.9	19.35	351	0.566	11.80	21.22
18.3	19.30	300	0.128	7.87	9.57
18.3	19.30	422	0.314	11.46	17.91
18.3	19.30	682	0.515	14.80	36.80

[a] Determined from the CO_2 evolved during storage.

[b] Assayed by TLC-UV technique.

[c] Determined by the percentage of discolored kernels per 50g sample.

Table Ic. Ergosterol Content, Dry Matter Loss and Discolored Kernel in Long Grain (Newrex) Rough Rice Stored at ~16% Moisture

Temperature (^oC)	Moisture (%)	Storage time, h	Dry matter[a] loss, %	Ergosterol[b] µg/g	Discolored[c] kernels, %
35.0	15.7	180	0.147	3.39	1.11
35.0	15.7	278	0.249	4.36	6.24
35.0	15.7	327	0.386	7.95	18.34
35.0	15.7	351	0.519	10.82	25.41
29.4	15.6	275	0.125	3.96	0.92
29.4	15.6	425	0.232	3.58	4.34
29.4	15.6	550	0.369	4.17	6.55
23.9	15.6	351	0.091	3.02	0.00
23.9	15.6	686	0.222	4.36	3.47
23.9	15.6	927	0.386	5.36	5.80
23.9	15.6	1114	0.481	5.75	5.39
18.3	16.4	567	0.091	3.65	0.00
18.3	16.4	895	0.222	4.56	1.28
18.3	16.4	1157	0.339	5.60	2.45

[a] Determined from the CO_2 evolved during storage.

[b] Assayed by TLC-UV technique.

[c] Determined by the percentage of discolored kernels per 50g sample.

Table IIa. Ergosterol Content, Dry Matter Loss and Discolored kernels in Medium Grain (Nato) Rough Rice Stored at ~20% Moisture

Temperature (°C)	Moisture (%)	Storage time, h	Dry matter[a] loss, %	Ergosterol[b] µg/g	Discolored[c] kernels, %
35.0	18.9	138	0.130	4.48	4.53
35.0	18.9	216	0.320	7.47	7.61
35.0	18.9	258	0.321	8.13	10.27
35.0	18.9	381	0.722	12.18	24.28
29.4	20.0	108	0.193	6.16	8.40
29.4	20.0	181	0.321	8.76	15.97
29.4	20.0	226	0.404	20.85	36.01
23.9	20.0	479	0.123	4.44	6.64
23.9	20.0	787	0.375	7.10	14.79
23.9	20.0	1363	0.426	11.62	25.05
18.3	20.0	404	0.105	3.85	2.63
18.3	20.0	882	0.183	4.53	4.69
18.3	20.0	1218	0.306	4.87	8.83
18.3	20.0	2060	0.456	6.48	16.83

a Determined from the CO_2 evolved during storage.

b Assayed by TLC-UV technique.

c Determined by the percentage of discolored kernels per 50g sample.

Table IIb. Ergosterol Content, Dry Matter Loss and Discolored Kernels in Medium Grain (Nato) Rough Rice Stored at ~18% Moisture

Temperature (°C)	Moisture (%)	Storage time, h	Dry matter[a] loss, %	Ergosterol[b] µg/g	Discolored[c] kernels, %
35.0	17.3	228	0.119	4.50	5.54
35.0	17.3	327	0.220	5.90	8.59
35.0	17.3	424	0.336	8.36	11.14
35.0	17.3	549	0.467	11.66	17.05
29.4	17.2	275	0.124	4.64	2.23
29.4	17.2	686	0.242	5.12	7.63
29.4	17.2	807	0.352	6.88	9.20
29.4	17.2	949	0.458	9.20	12.24
23.9	18.2	423	0.110	3.70	1.89
23.9	18.2	804	0.240	5.70	4.96
23.9	18.2	1071	0.297	7.70	6.79
23.9	18.2	1163	0.496	9.34	8.49
18.3	18.8	835	0.128	5.46	5.70
18.3	18.8	1218	0.228	9.24	11.02
18.3	18.8	1563	0.378	19.74	41.70
18.3	18.8	2060	0.542	7.43	9.86

a Determined from the CO_2 evolved during storage.

b Assayed by TLC-UV technique.

c Determined by the percentage of discolored kernels per 50g sample.

Table IIc. Ergosterol Content, Dry Matter Loss and Discolored Kernels in Medium Grain (Nato) Rough Rice Stored at ~16% Moisture

Temperature (°C)	Moisture (%)	Storage time, h	Dry matter[a] loss, %	Ergosterol[b] µg/g	Discolored[c] kernels, %
35.0	16.4	327	0.130	3.32	2.33
35.0	16.4	638	0.345	5.36	9.02
35.0	16.4	663	0.433	8.50	14.74
29.4	15.7	326	0.094	3.78	1.07
29.4	15.7	901	0.223	4.23	4.10
29.4	15.7	1313	0.342	4.70	6.54
29.4	15.7	1662	0.492	5.85	10.37
23.9	15.6	804	0.109	3.28	1.53
23.9	15.6	1823	0.250	4.67	5.98
18.3	17.5	921	0.124	2.96	0.45
18.3	17.5	1608	0.285	3.47	3.88

[a] Determined from the CO_2 evolved during storage.

[b] Assayed by TLC-UV technique.

[c] Determined by the percentage of discolored kernels per 50g sample.

Table III. Dry Matter Loss, Ergosterol Content, and Percentage Discolored Kernels for Hand-Threshed Long Grain (Arkansas 007) Rough Rice During Storage.

Temperature, (°C)	Moisture, (%)	Storage, time, h	DML,[a] %	Ergosterol,[b] µg/g	Discolored[c] kernels, %
23.9	19.73	153	0.120	5.10	0.60
23.9	19.73	321	0.267	7.60	1.69
23.9	19.73	522	0.430	9.00	4.12
35.0	19.99	105	0.224	5.84	2.54
35.0	19.99	250	0.544	7.37	8.00
35.0	19.99	297	0.637	7.84	9.41
35.0	19.99	345	0.676	10.96	11.35
35.0	16.80	118	0.162	5.55	1.09
35.0	16.80	237	0.324	6.30	3.17
35.0	16.80	309	0.413	6.98	4.29

Table IV. Dry Matter Loss, Ergosterol Content, and Percentage Discolored Kernels for Mechanically-Threshed Long Grain (Arkansas 007) Rough Rice During Storage.

Temperature (°C)	Moisture (%)	Storage, time, h	DML,[a] %	Ergosterol,[b] µg/g	Discolored[c] kernels, %
23.9	19.80	104	0.206	7.13	5.68
23.9	19.80	131	0.313	11.30	13.50
23.9	19.80	251	0.402	19.80	33.18
35.0	19.83	105	0.333	11.01	12.71
35.0	19.83	153	0.579	13.45	21.30
35.0	19.83	250	1.020	18.36	27.06
35.0	17.11	141	0.141	4.80	1.77
35.0	17.11	237	0.297	5.80	2.82
35.0	17.11	184	0.330	5.21	3.35
35.0	17.11	333	0.549	6.09	4.80

[a] Determined from the CO_2 evolved during storage.

[b] Assayed by TLC-UV technique.

[c] Determined by the percentage of discolored kernels per 50g sample.

Table V. Coefficients A, B and C in Equation (6) for Ergosterol Content in Newrex and Nato Rough Rice Stored at 18.3°, 23.9°, 29.4° and 35°C, and Moisture Ranging from 15.6 to 20%.

Variety	Constant	Coefficient[a]	Confidence Interval (95%) Lower	Confidence Interval (95%) Upper	T-value
Newrex	A	2.04×10^{-6}	2.10×10^{-7}	3.88×10^{-6}	2.27
	B	0.106	0.100	0.112	34.98
	C	0.439	0.393	0.486	19.19
Nato	A	6.50×10^{-7}	-1.30×10^{-7}	1.44×10^{-6}	1.71
	B	0.151	0.138	0.163	24.75
	C	0.350	0.299	0.401	14.08

[a] As obtained from non-linear-iteration procedure (SAS)

Test equality of the constants;

Ho: $A_{(Newrex)} = A_{(Nato)}$

$$t_c = \frac{2.04 - 0.65}{0.39} = 3.56^{**}$$

Ho: $B_{(Newrex)} = B_{(Nato)}$

$$t_c = \frac{0.151 - 0.106}{0.0061} = 7.38^{**}$$

Ho: $C_{(Newrex)} = C_{(Nato)}$

$$t_c = \frac{0.4395 - 0.3501}{0.0248} = 3.61^{**}$$

Table VI. Residual Standard Error[a] of Ergosterol for Newrex and Nato Rough Rice

Variety	No. of Observations	Mean Deviation	Minimum Value	Maximum Value	Standard Error of Mean	T-value
Newrex	35	0.590	-4.30	5.95	0.3906	1.51^{ns}
Nato	35	0.101	-2.81	2.53	0.1847	0.544^{ns}

[a] Computed from the residual of the observed and the predicted ergosterol using Equation (6), and the constants in Table V.

Table VII. Coefficients A, B and C in Equation (6) for Ergosterol Content in Arkansas 007 Rough Rice Stored at Temperature 23.9^{o} and 35^{o}C, and Moisture 17 and 20%.

Treatment	Constant	Coefficient[a]	Confidence Interval (95%)		T-value
			Lower	Upper	
Hand-Thereshed					
	A	3.9×10^{-6}	-2.33×10^{-5}	3.02×10^{-5}	0.355
	B	0.042	0.016	0.069	3.74
	C	0.402	0.045	0.759	2.66
Mechanically-Threshed					
	A	1.82×10^{-6}	-1.48×10^{-6}	1.48×10^{-6}	0.003
	B	0.071	-23.18	23.33	0.008
	C	0.450	0.217	0.684	5.36

[a] Obtained from non-linear procedure (SAS).

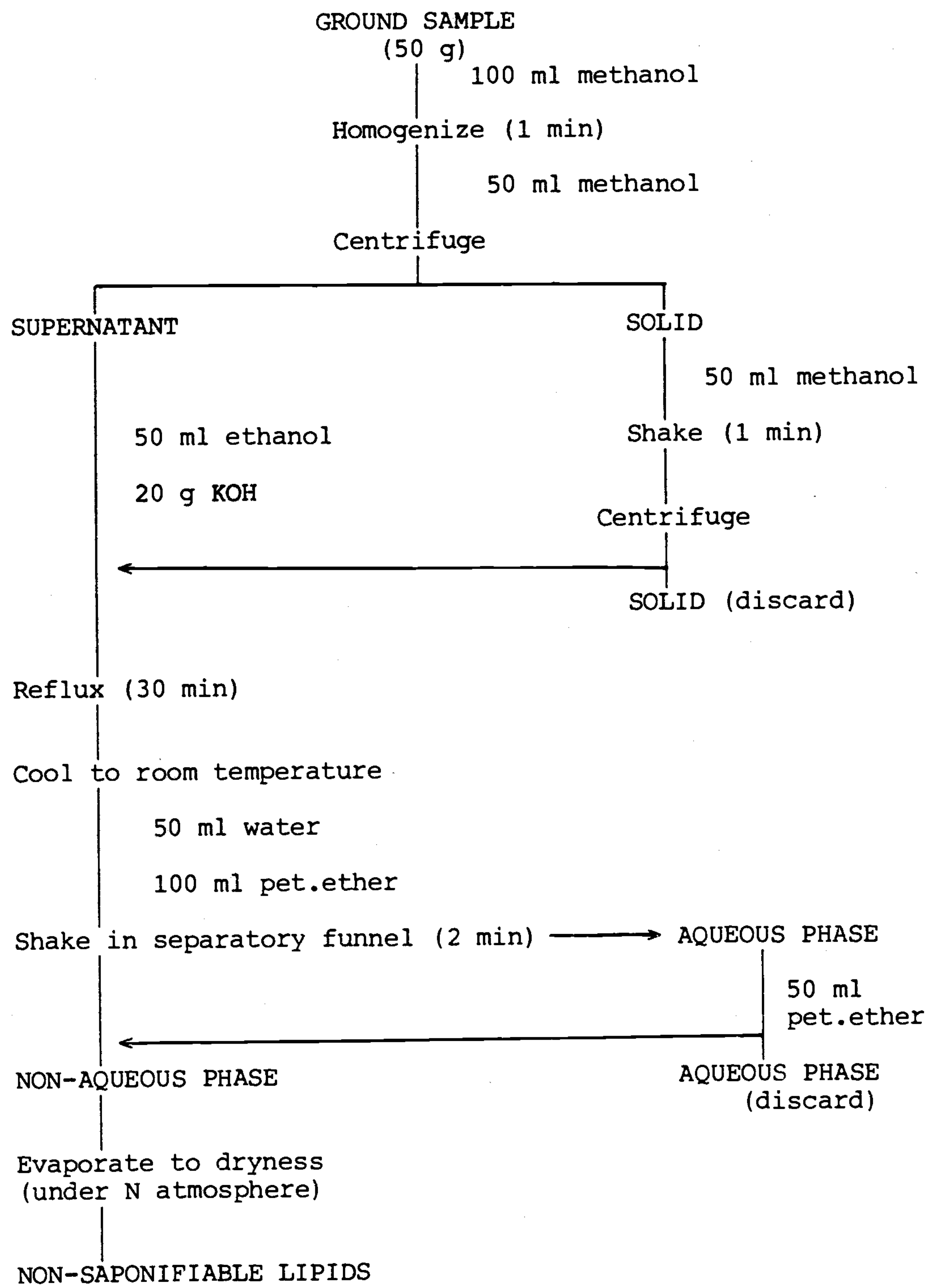


Fig. 1. Schematic diagram for non-saponifiable lipid extraction

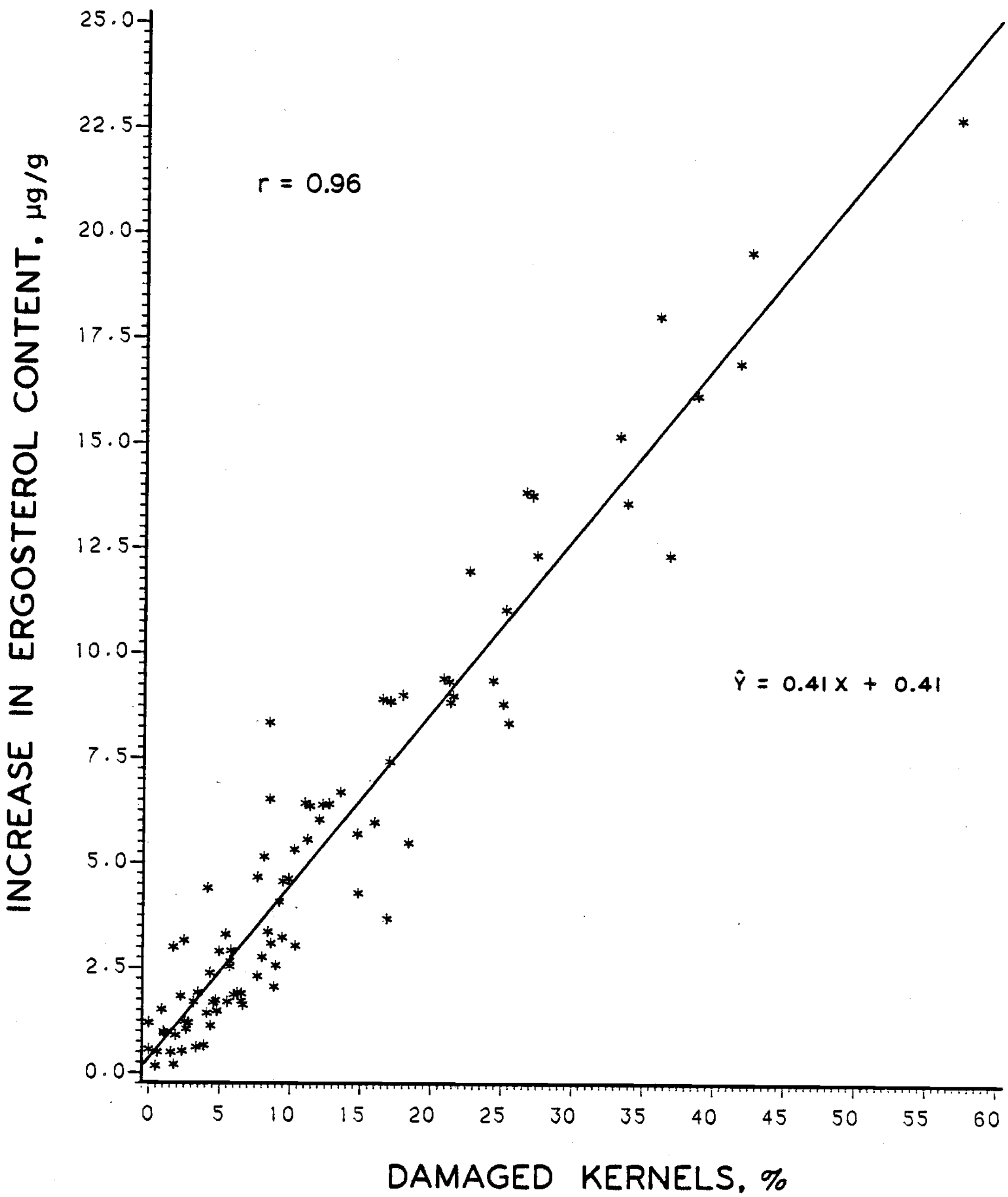


FIG. 2. RELATIONSHIP BETWEEN THE INCREASE IN ERGOSTEROL CONTENT AND THE PERCENTAGE DAMAGED (DISCOLORED) KERNELS OF NEWREX (LONG GRAIN), NATO (MEDIUM GRAIN) AND ARKANSAS 007 (LONG GRAIN) ROUGH RICE.

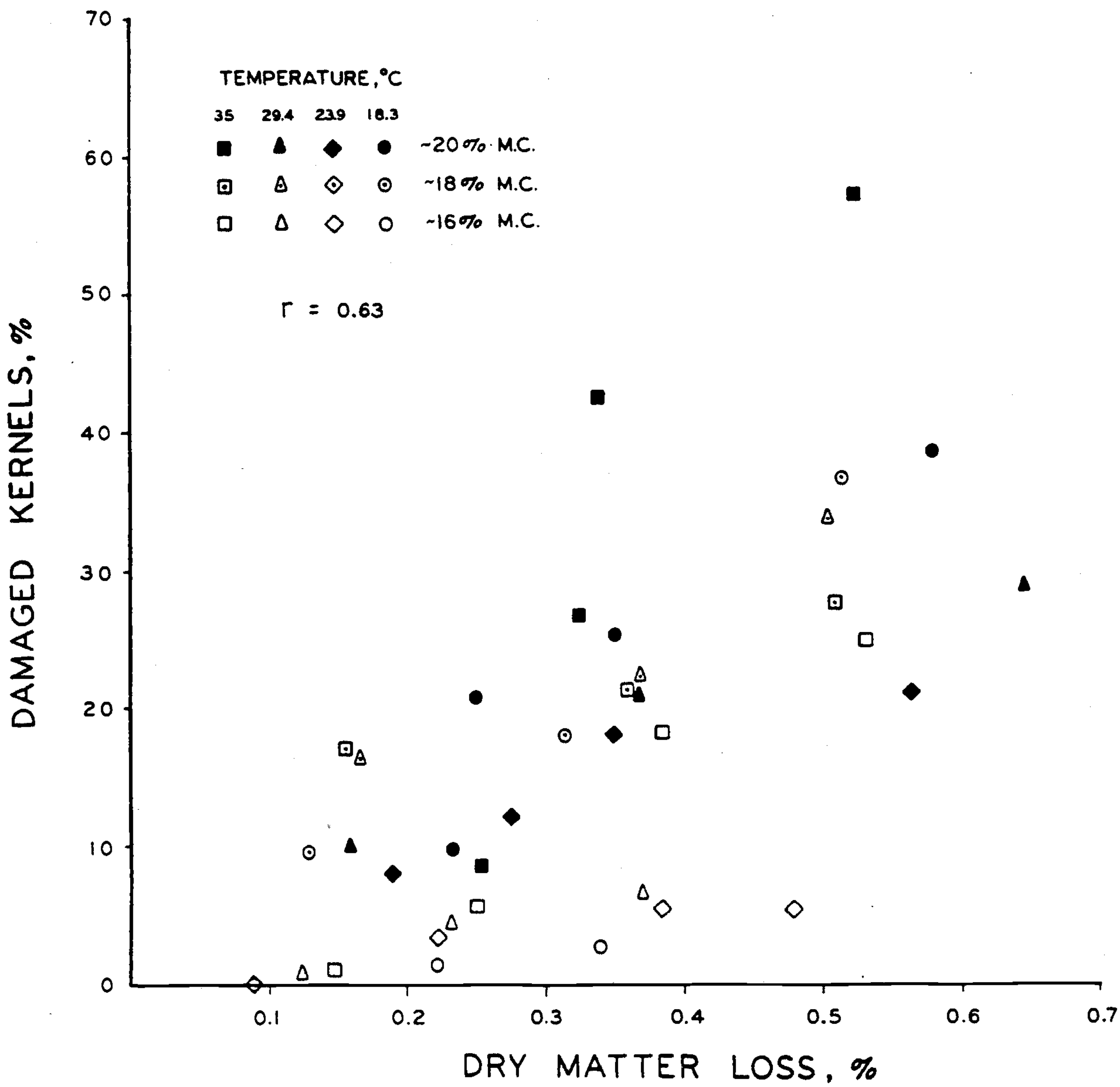


FIG. 3. RELATIONSHIP BETWEEN THE PERCENTAGE DAMAGED (DISCOLORED) KERNELS AND THE DML IN 'NEWREX' LONG GRAIN ROUGH RICE

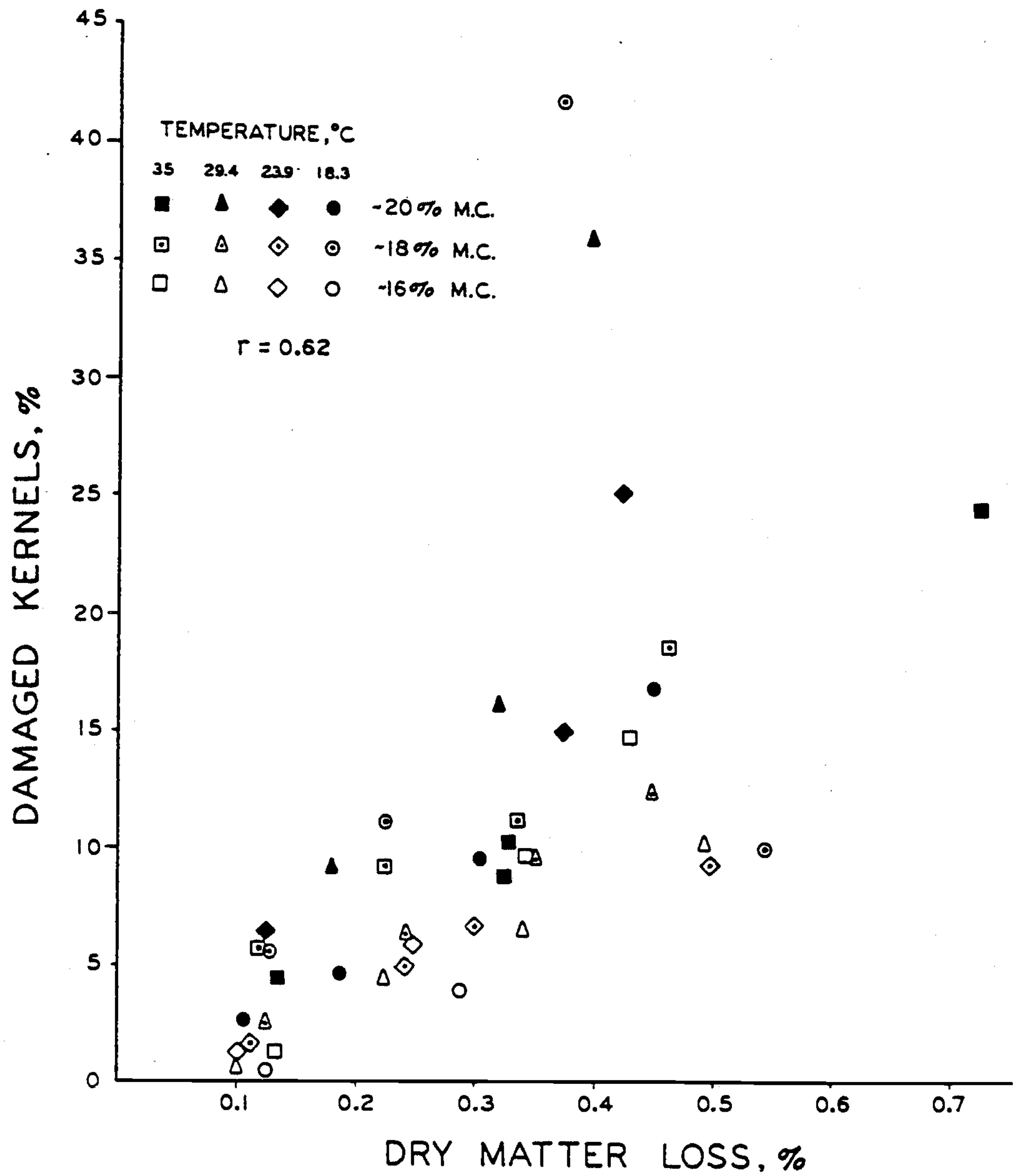


FIG. 4. RELATIONSHIP BETWEEN THE PERCENTAGE DAMAGED (DISCOLORED) KERNELS AND THE DML IN 'NATO' MEDIUM GRAIN ROUGH RICE

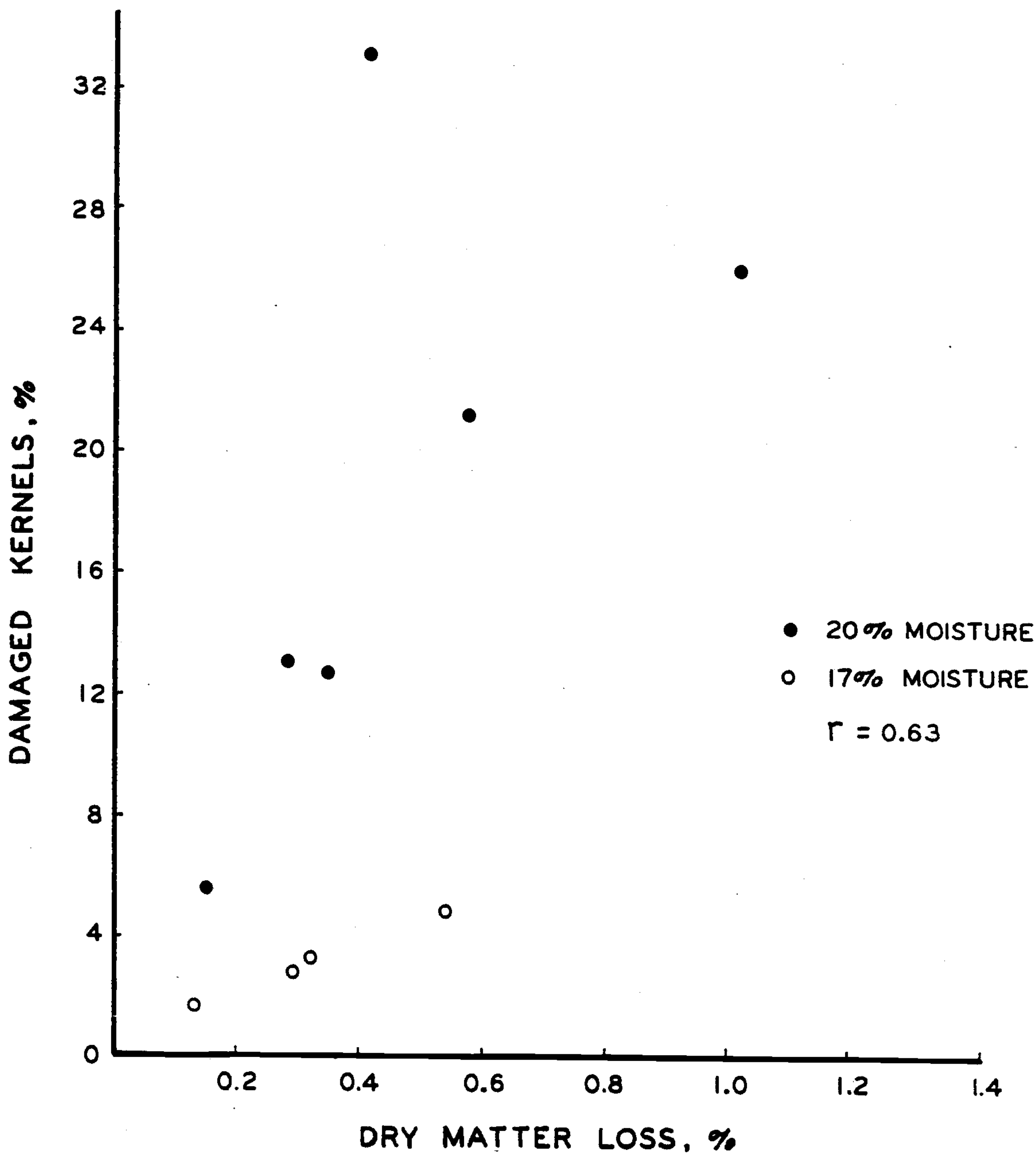


FIG. 5. RELATIONSHIP BETWEEN THE PERCENTAGE DAMAGED (DISCOLORED) KERNELS AND THE DML IN THE MECHANICALLY-THRESHED 'ARKANSAS 007' LONG GRAIN ROUGH RICE

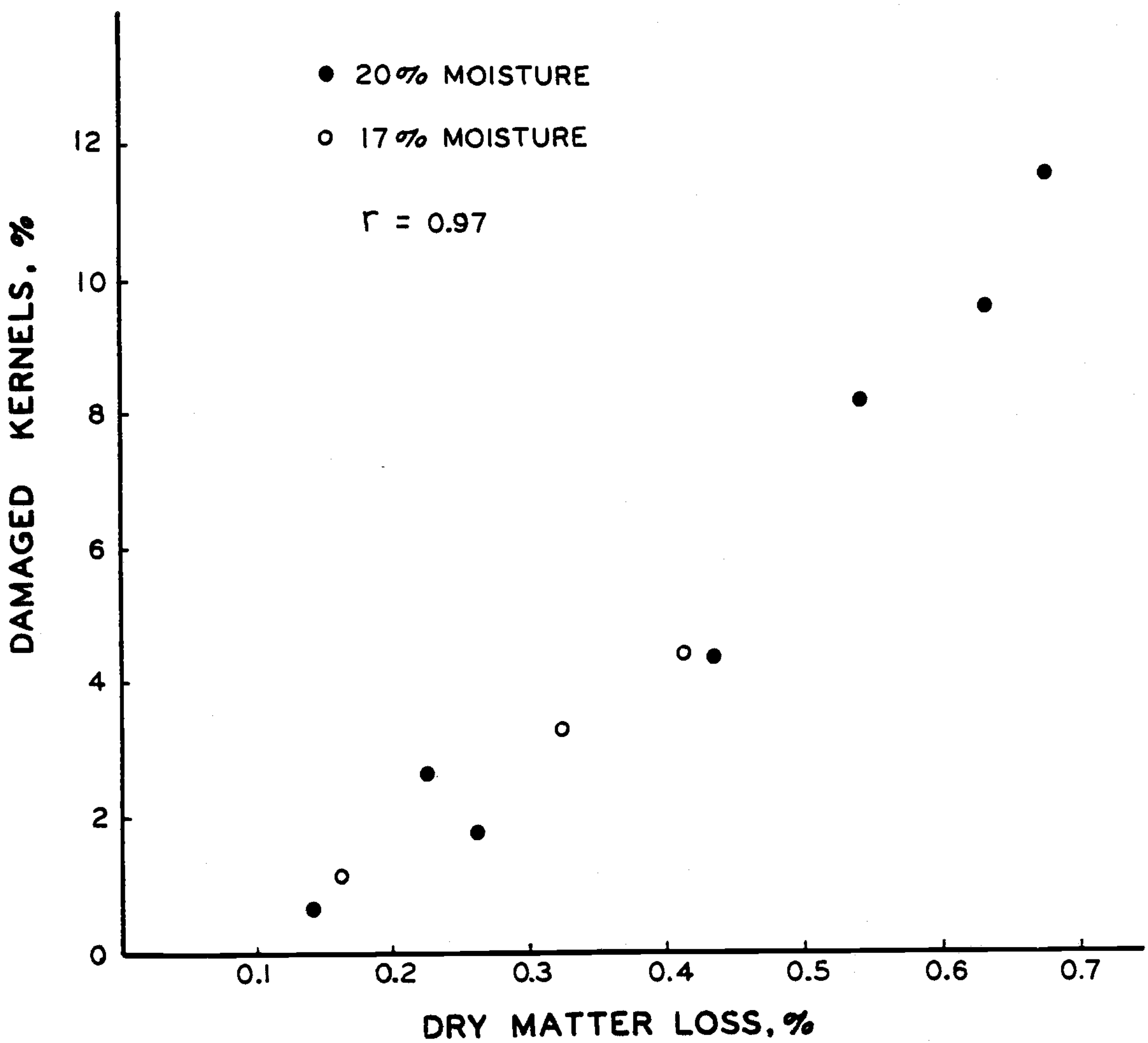


FIG. 6. RELATIONSHIP BETWEEN THE PERCENTAGE DAMAGED (DISCOLORED) KERNELS AND THE DML IN THE HAND-THRESHED 'ARKANSAS 007' LONG GRAIN ROUGH RICE

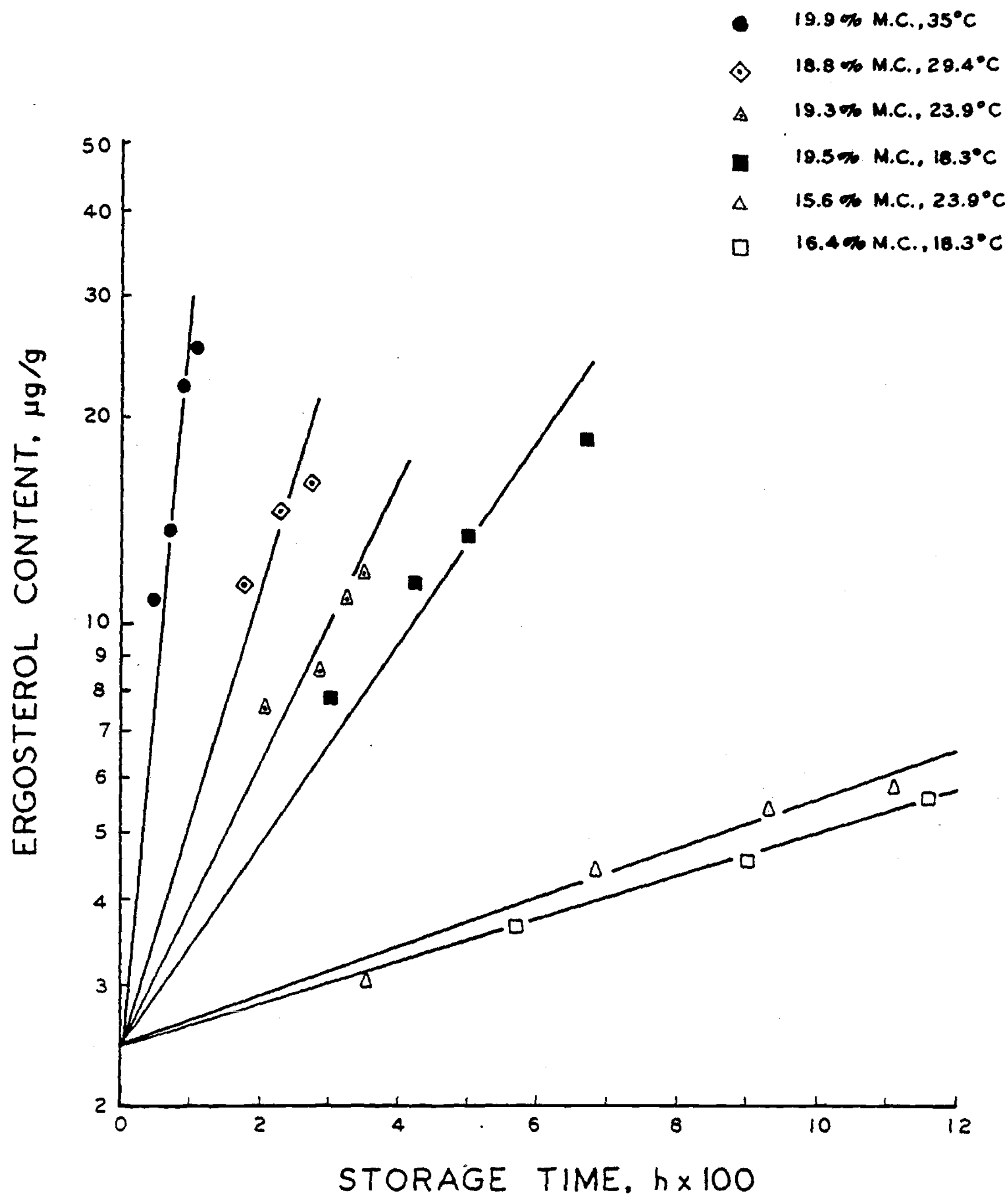


FIG. 7. RELATIONSHIP BETWEEN ERGOSTEROL CONTENT AND STORAGE TIME OF NEWREX LONG GRAIN ROUGH RICE.

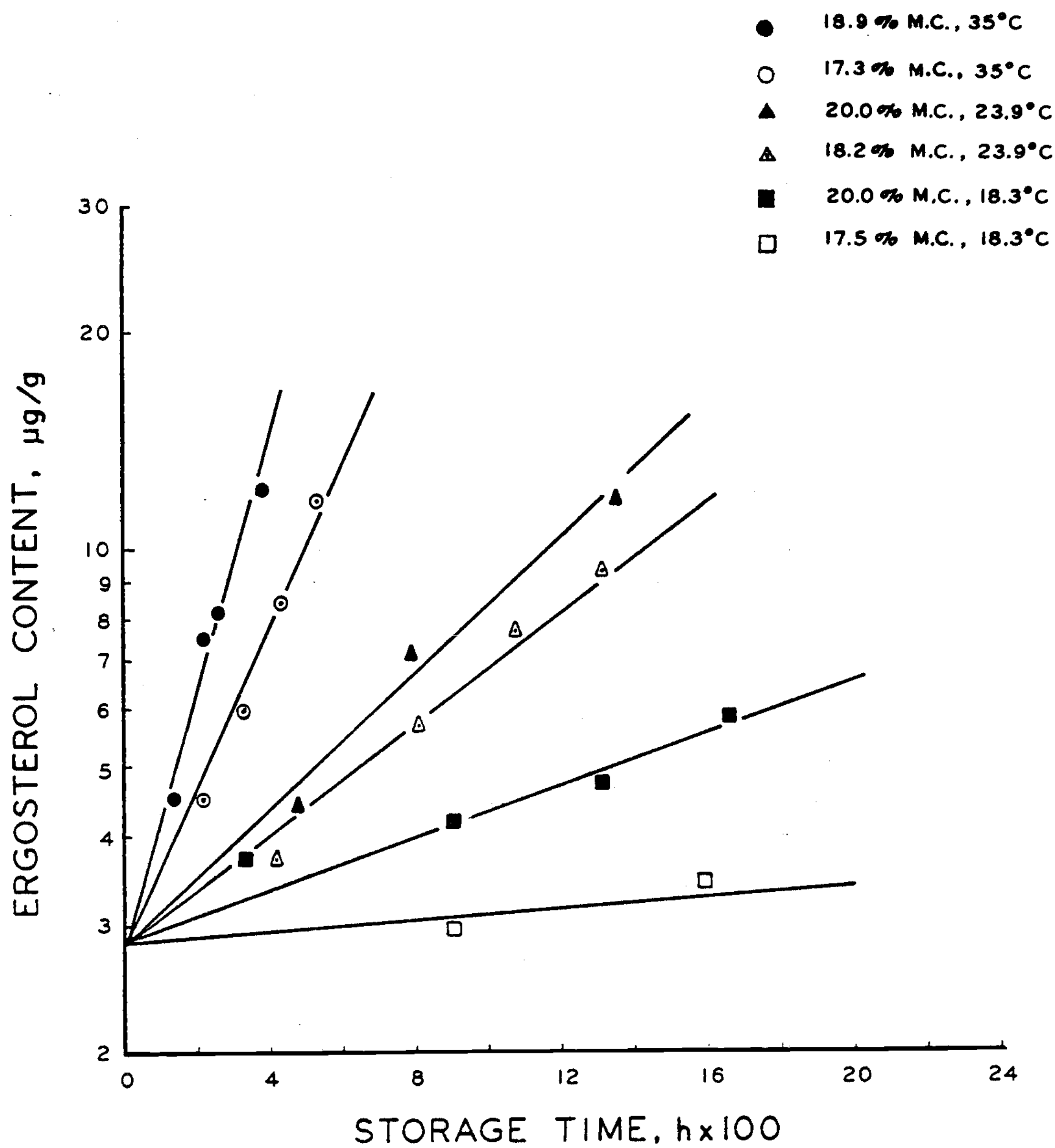


FIG. 8. RELATIONSHIP BETWEEN ERGOSTEROL CONTENT AND STORAGE TIME OF NATO MEDIUM GRAIN ROUGHRICE.

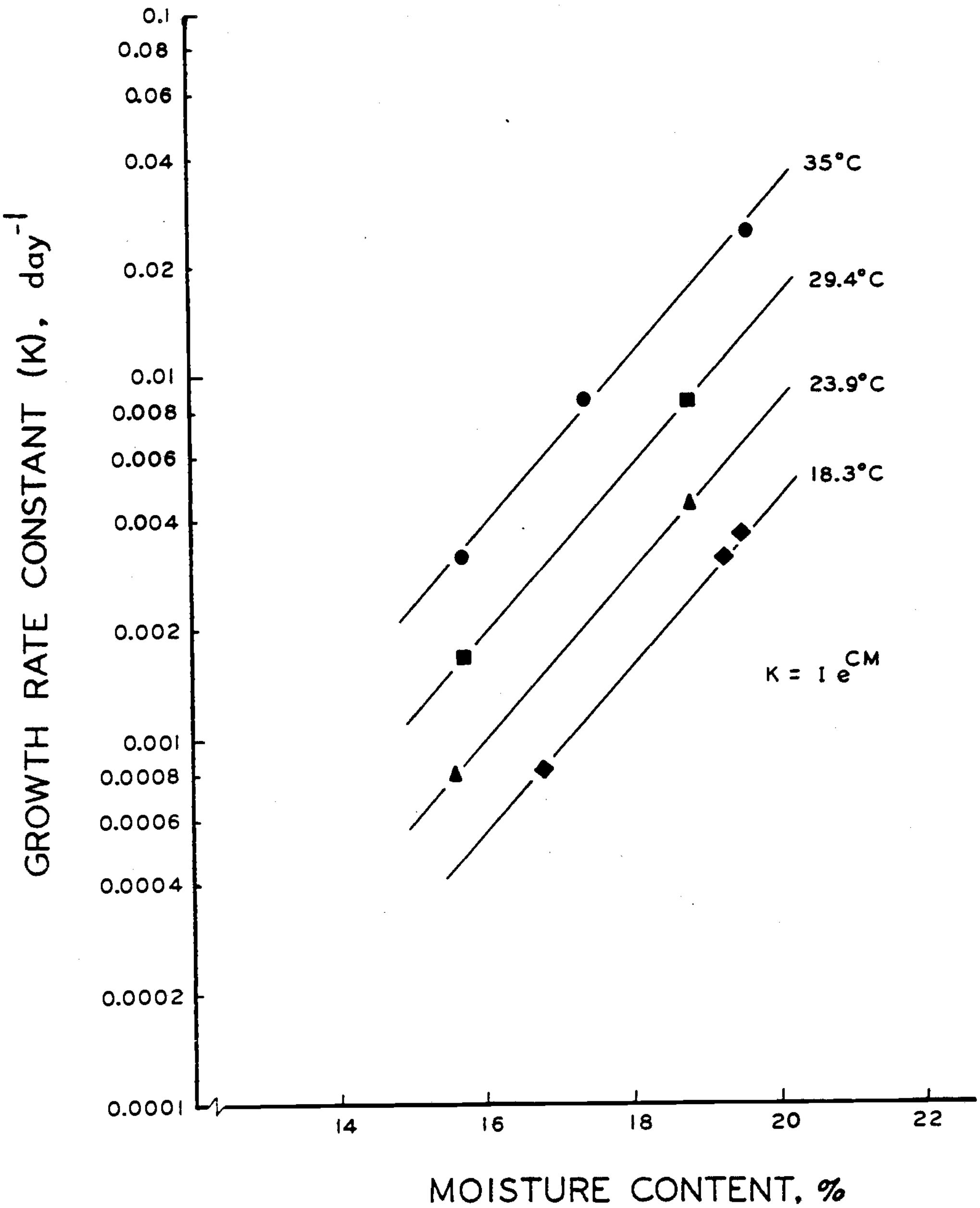


FIG. 9. RELATIONSHIP BETWEEN THE GROWTH RATE CONSTANT (K) AND THE MOISTURE VARIABLE FOR NEWREX LONG GRAIN ROUGH RICE.

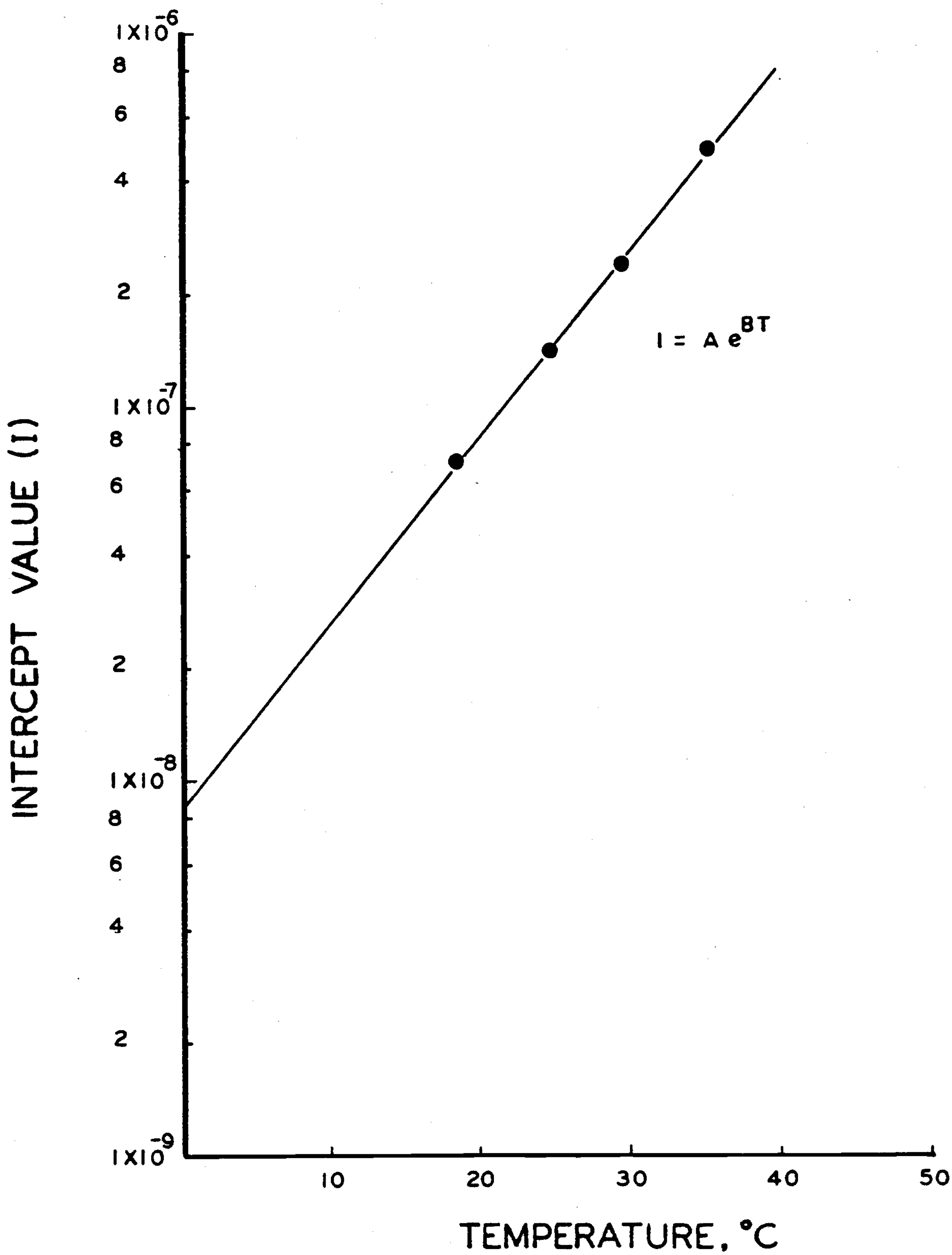


FIG. 10. RELATIONSHIP BETWEEN THE VALUES OF INTERCEPT (I) IN FIGURE 9 AND THE VARIABLE TEMPERATURE FOR NEWREX LONG GRAIN ROUGH RICE.

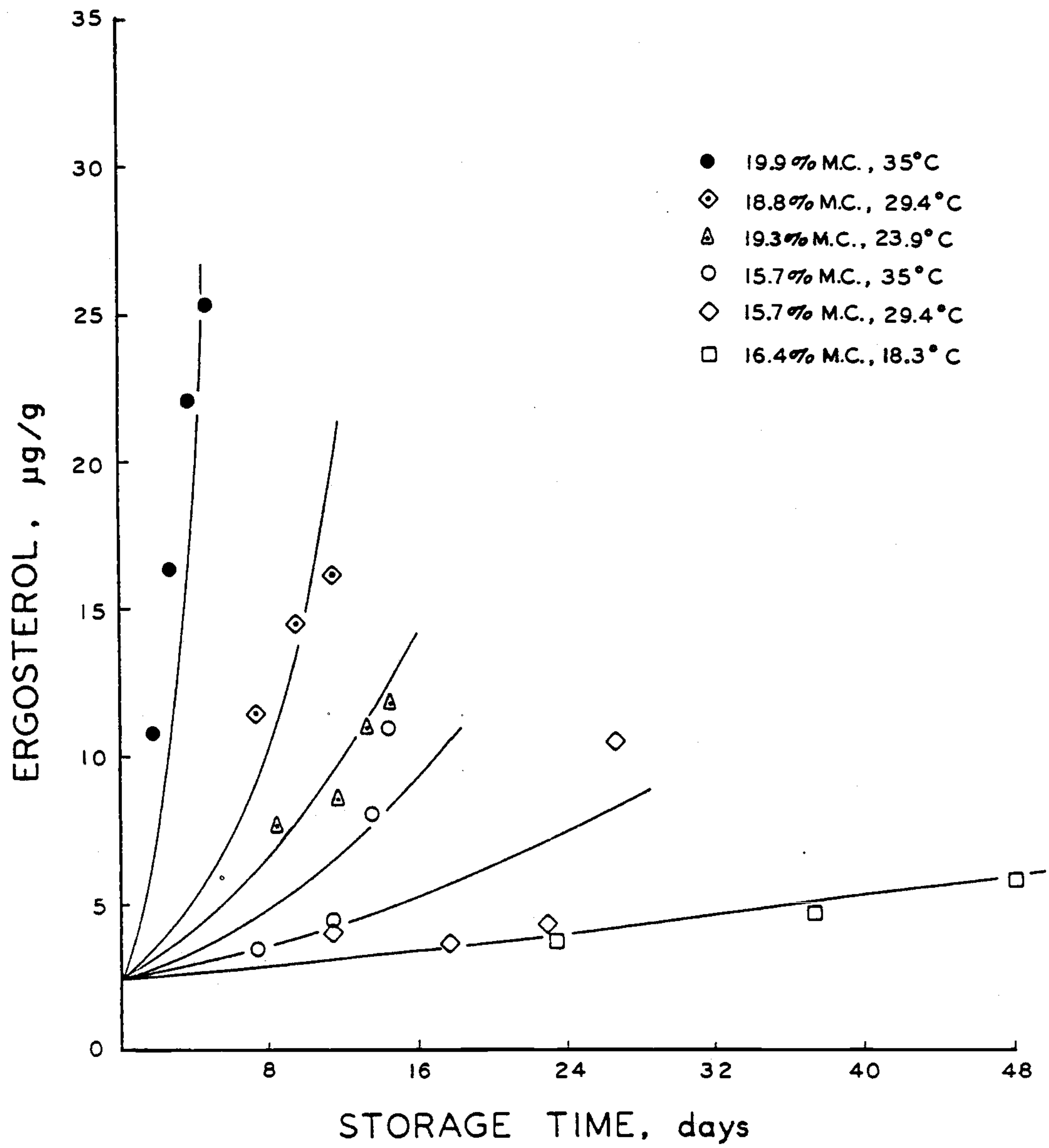


FIG. 11. PLOT OF THE OBSERVED AND THE PREDICTED (———) ERGOSTEROL USING EQUATION (6) FOR NEWREX LONG GRAIN ROUGH RICE.

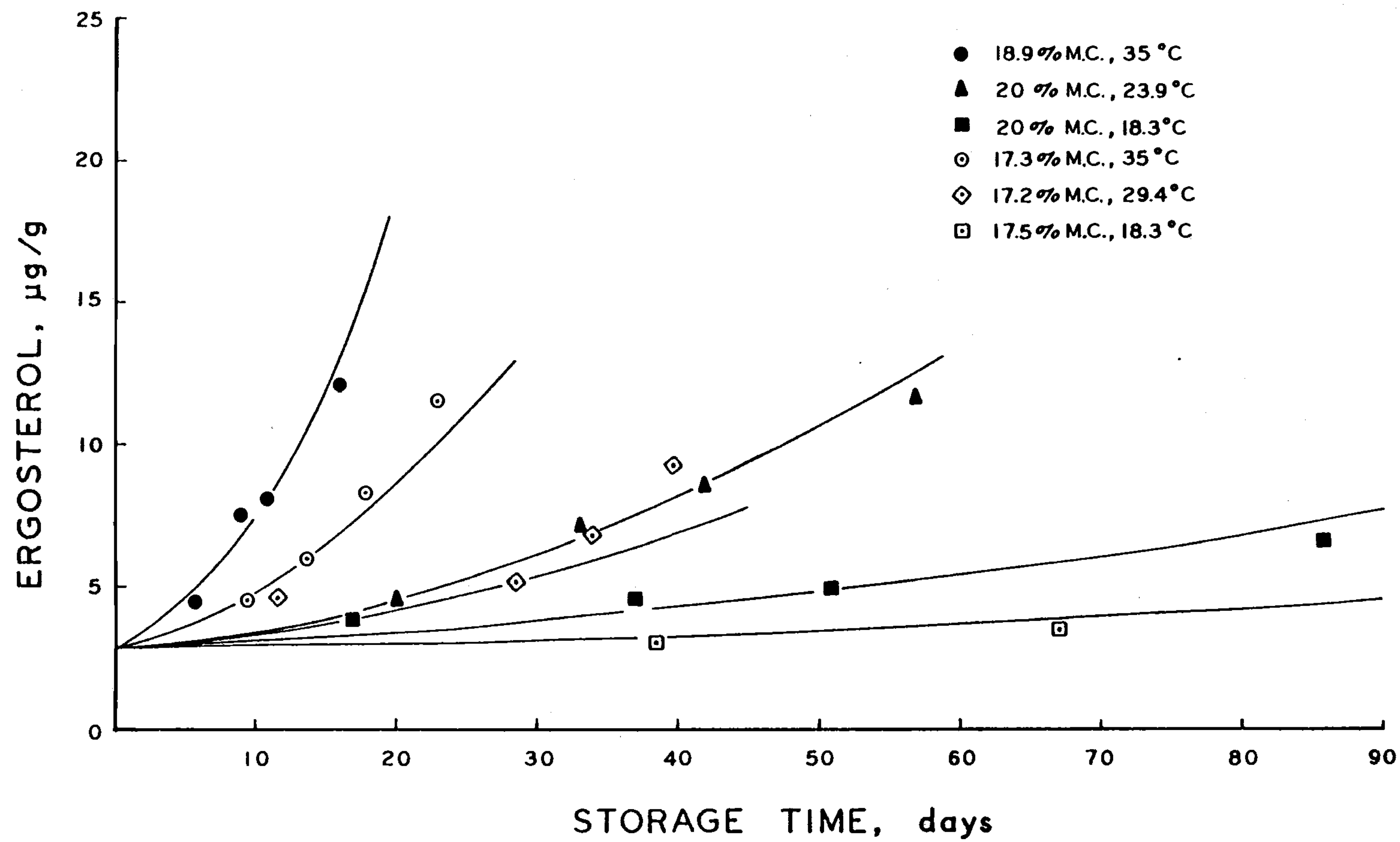


FIG. 12. PLOT OF THE OBSERVED AND THE PREDICTED (———) ERGOSTEROL USING EQUATION (6) FOR NATO MEDIUM GRAIN ROUGH RICE.

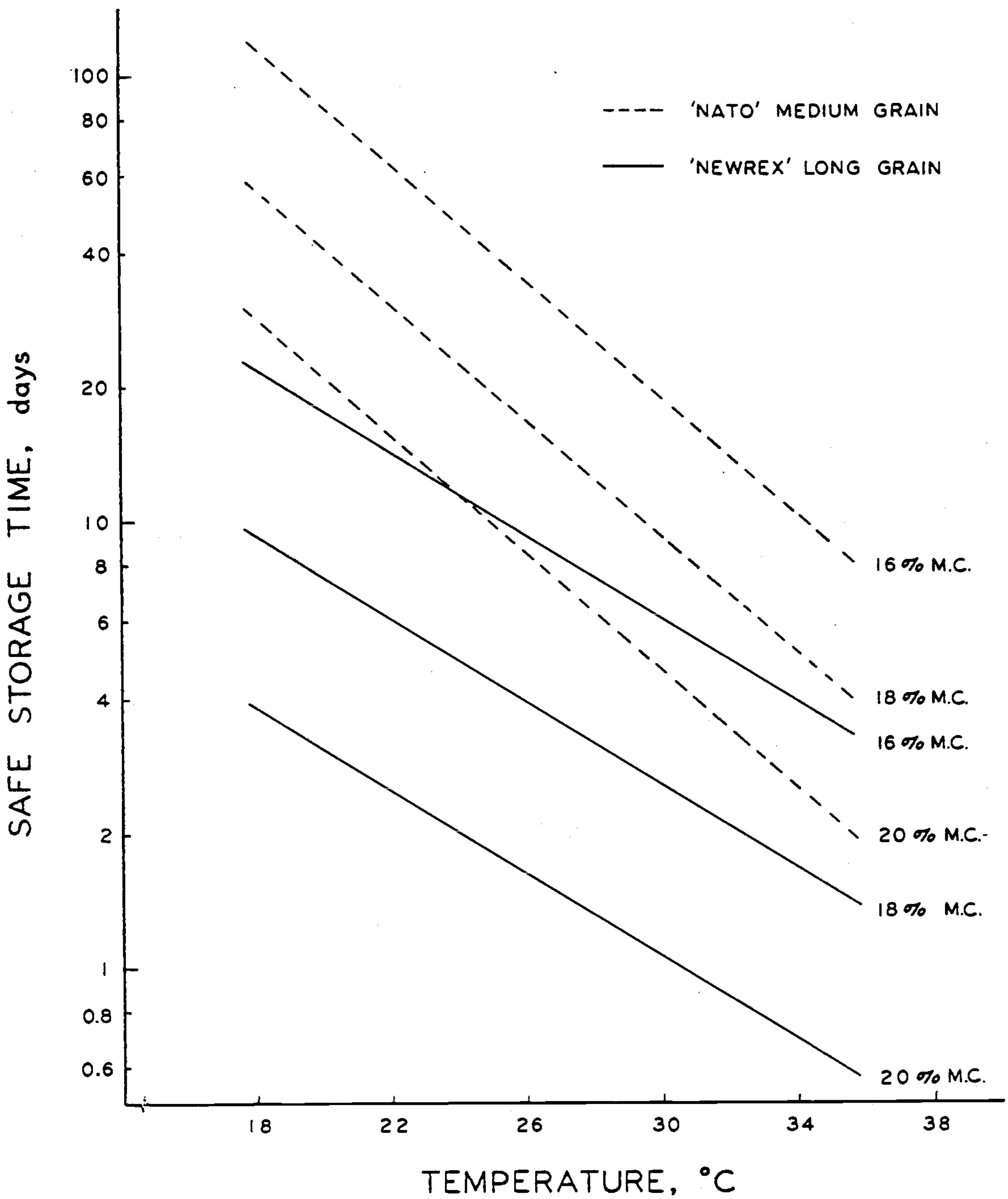


FIG. 13. PREDICTED SAFE STORAGE TIME FOR NEWREX (LONG GRAIN) AND NATO (MEDIUM GRAIN) ROUGH RICE BEFORE DROPPING BELOW U.S. No. 2 GRADE.

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ACKNOWLEDGEMENTS

The author wishes to express his gratitude and appreciation to Dr. Paul A. Seib, Department of Grain Science and Industry, KSU, major professor, for his guidance, assistance, and patience throughout his graduate program and in the preparation of this manuscript. Sincere appreciation is also extended to Dr. Larry M. Seitz, U.S. Grain Marketing Research Center, USDA, for his guidance and help in the development of the TLC-UV method for ergosterol determination, his valuable suggestions to improve this manuscript, and for serving in the author's graduate committee; to Dr. Do Sup Chung, Department of Agricultural Engineering, KSU, for his valuable suggestions in the development of the ergosterol model and for serving on the graduate committee; and Dr. Charles W. Deyoe, Department of Grain Science and Industry, KSU, for the financial assistance extended to this research project and for serving on the graduate committee. Acknowledgement is also expressed to Ms. Rosemary Burroughs for her help in editing the manuscript on Ergosterol Methodology and correcting this dissertation.

This research would not have been possible without Dr. Gerald Kline's permission allowing the author the use of the facilities at the Agricultural Research Experiment Station, Ames, Iowa, and the technical assistance of Mr. Vergil Haynes and his assistants in setting up the carbon dioxide absorption system.

Appreciation is also extended to Dr. Harry B. Pfost for his concern and invaluable help, to the International Research and Development Centre at Ottawa, Canada for providing the author a year-training scholarship at the Department of Grain Science and Industry, KSU, to the Ministry of Agriculture of Thailand for permitting the author a study leave, and to the Department of Grain Science and Industry, KSU for providing a graduate assistanship.

The author also expresses his thanks to Dr. George Milliken for his help in the statistical analysis, to Dr. Ulyses Acasio and his son, Erwin for their help in securing the samples, and to Staffs and friends at the Department of Grain Science and Industry, KSU, for their help and friendship during the author's stay in that department.

This could not have been possible without the help, support, and love from his family.

APPENDIX A

MOISTURE CONTENT DURING STORAGE OF ROUGH RICE SAMPLES

Table IIIa. Moisture Content (MC, wet basis) During Storage of Long Grain (Newrex) Rough Rice Samples.

Sample code	Temperature, °C	Storage Time, h	Ave. DML, %	Sample Weight, g Initial	Sample Weight, g Final	Sample Moisture, % Initial	Sample Moisture, % Final
722-35-L	35	43	0.253	214.0	213.1	20.00	19.90
728-35-L	35	43	0.253	214.0	213.1	20.00	19.90
716-35-L	35	66	0.335	214.0	212.6	20.00	19.70
828-35-L	35	66	0.335	214.0	212.8	20.00	19.80
734-35-L	35	89	0.340	214.0	212.8	20.00	19.90
822-35-L	35	89	0.340	214.0	212.8	20.00	19.90
710-35-L	35	89	0.340	214.0	212.6	20.00	19.80
704-35-L	35	114	0.525	214.0	212.4	20.00	19.80
746-35-L	35	114	0.525	214.0	212.4	20.00	19.80
834-35-L	35	114	0.525	214.0	212.3	20.00	19.80
840-35-L	35	114	0.525	214.0	212.7	20.00	19.90
						Ave. final MC =	19.85
801-35-L	35	136	0.155	366.0	357.0	18.00	16.00
807-35-L	35	136	0.155	366.0	360.0	18.00	16.70
713-35-L	35	179	0.361	366.0	360.2	18.00	17.00
843-35-L	35	179	0.361	366.0	361.6	18.00	17.30
737-35-L	35	228	0.510	366.0	361.2	18.00	17.30
825-35-L	35	228	0.510	366.0	363.4	18.00	17.80
837-35-L	35	228	0.510	366.0	362.6	18.00	17.60
						Ave. final MC =	17.10
732-35-L	35	180	0.147	360.0	359.2	16.00	15.90
744-35-L	35	180	0.147	360.0	358.6	16.00	15.80
814-35-L	35	180	0.147	360.0	358.8	16.00	15.40
702-35-L	35	278	0.249	360.0	356.7	16.00	15.60
714-35-L	35	278	0.249	360.0	357.8	16.00	15.80
726-35-L	35	327	0.386	360.0	358.6	16.00	16.00
738-35-L	35	327	0.386	360.0	358.8	16.00	16.00
826-35-L	35	327	0.386	360.0	357.6	16.00	15.70
708-35-L	35	351	0.527	360.0	357.0	16.00	15.70
720-35-L	35	351	0.527	360.0	356.9	16.00	15.70
832-35-L	35	351	0.527	360.0	356.7	16.00	15.60
						Ave. final MC =	15.74

Table IIIb. Moisture Content (MC, wet basis) During Storage of Long Grain (Newrex) Rough Rice Samples

Sample code	Temperature, °C	Storage Time, h	Ave. DML, %	Sample Weight, g		Sample Moisture, %	
				Initial	Final	Initial	Final
519-29-L	29.4	179	0.167	360.0	361.4	18.00	18.40
619-29-L	29.4	179	0.167	360.0	375.2	18.00	17.50
537-29-L	29.4	179	0.167	360.0	360.3	18.00	18.20
531-29-L	29.4	228	0.372	360.0	361.5	18.00	18.70
613-29-L	29.4	228	0.372	360.0	360.5	18.00	18.50
607-29-L	29.4	275	0.505	360.0	358.3	18.00	18.10
613-29-L	29.4	275	0.505	360.0	360.0	18.00	19.30
						Ave. final MC =	18.40
514-29-L	29.4	275	0.125	360.0	357.4	16.00	15.50
526-29-L	29.4	275	0.125	360.0	375.4	16.00	15.50
608-29-L	29.4	275	0.125	360.0	358.8	16.00	15.80
538-29-L	29.4	425	0.232	360.0	357.0	16.00	15.50
544-29-L	29.4	425	0.232	360.0	357.2	16.00	15.50
644-29-L	29.4	425	0.232	360.0	357.4	16.00	15.60
502-29-L	29.4	550	0.369	360.0	357.4	16.00	15.70
626-29-L	29.4	550	0.369	360.0	358.8	16.00	16.00
						Ave. final MC =	15.65

Table IIIc. Moisture Content (MC, wet basis) During Storage of Long Grain (Newrex) Rough Rice Samples.

Sample code	Temperature, °C	Storage Time, h	Ave. DML, %	Sample Weight, g		Sample Moisture, %	
				Initial	Final	Initial	Final
340-24-L	23.9	140	0.151	312.5	310.6	19.80	19.50
440-24-L	23.9	140	0.151	312.5	310.6	19.80	19.50
428-24-L	23.9	140	0.151	312.5	310.6	19.80	19.50
322-24-L	23.9	236	0.319	312.5	310.5	19.80	19.50
446-24-L	23.9	236	0.319	312.5	308.8	19.80	19.10
304-24-L	23.9	310	0.367	312.5	309.1	19.80	19.30
328-24-L	23.9	310	0.367	312.5	309.7	19.80	19.50
404-24-L	23.9	310	0.367	312.5	308.6	19.80	19.20
434-24-L	23.9	310	0.367	312.5	308.5	19.80	19.20
334-24-L	23.9	453	0.621	312.5	310.2	19.80	19.80
422-24-L	23.9	453	0.621	312.5	308.0	19.80	19.20
410-24-L	23.9	453	0.621	312.5	306.9	19.80	18.90
						Ave. final MC =	19.35
301-24-L	23.9	206	0.191	360.0	365.0	18.00	19.50
313-24-L	23.9	206	0.191	360.0	366.7	18.00	19.60
419-24-L	23.9	206	0.191	360.0	366.7	18.00	19.60
319-24-L	23.9	238	0.276	360.0	366.2	18.00	19.60
331-24-L	23.9	238	0.276	360.0	336.7	18.00	19.70
425-24-L	23.9	238	0.276	360.0	367.2	18.00	19.80
307-24-L	23.9	323	0.352	360.0	367.2	18.00	19.90
431-24-L	23.9	323	0.352	360.0	367.4	18.00	19.90
437-24-L	23.9	323	0.352	360.0	367.1	18.00	19.90
325-24-L	23.9	351	0.566	360.0	367.5	18.00	20.10
343-24-L	23.9	351	0.566	360.0	367.2	18.00	20.10
413-24-L	23.9	351	0.566	360.0	368.8	18.00	20.00
						Ave. final MC =	19.80
302-24-L	23.9	351	0.091	360.0	356.0	16.00	15.10
408-24-L	23.9	351	0.091	360.0	356.0	16.00	15.10
414-24-L	23.9	351	0.091	360.0	365.0	16.00	15.10
402-24-L	23.9	686	0.222	360.0	357.0	16.00	15.60
432-24-L	23.9	686	0.222	360.0	358.7	16.00	15.90
320-24-L	23.9	927	0.386	360.0	359.5	16.00	16.20
444-24-L	23.9	927	0.386	360.0	357.4	16.00	15.70
308-24-L	23.9	1114	0.481	360.0	358.4	16.00	16.00
314-24-L	23.9	1114	0.481	360.0	359.0	16.00	16.20
332-24-L	23.9	1114	0.481	360.0	356.7	16.00	15.60
						Ave. final MC =	15.65

Table IIId. Moisture Content (MC, wet basis) During Storage of Long Grain (Newrex) Rough Rice Samples

Sample code	Temperature, °C	Storage Time, h	Ave. DML, %	Sample Weight, g		Sample Moisture, %	
				Initial	Final	Initial	Final
146-18-L	18.3	236	0.234	312.0	310.2	19.80	19.40
210-18-L	18.3	236	0.234	312.0	309.2	19.80	19.20
110-18-L	18.3	428	0.251	312.0	310.0	19.80	19.50
116-18-L	18.3	428	0.251	312.0	311.0	19.80	19.70
204-18-L	18.3	428	0.251	312.0	310.5	19.80	19.60
128-18-L	18.3	499	0.351	312.0	307.9	19.80	19.00
216-18-L	18.3	499	0.351	312.0	310.2	19.80	19.60
122-18-L	18.3	668	0.581	312.0	310.8	19.80	19.90
140-18-L	18.3	499	0.581	312.0	310.7	19.80	19.70
234-18-L	18.3	668	0.581	312.0	309.2	19.80	19.50
						Ave. final MC =	19.50
143-18-L	18.3	300	0.128	360.0	364.7	18.00	19.20
201-18-L	18.3	300	0.128	360.0	364.2	18.00	19.10
125-18-L	18.3	422	0.314	360.0	364.9	18.00	19.40
231-18-L	18.3	422	0.314	360.0	364.9	18.00	19.40
131-18-L	18.3	659	0.317	360.0	364.7	18.00	19.30
213-18-L	18.3	659	0.317	360.0	364.5	18.00	19.30
101-18-L	18.3	682	0.515	360.0	365.2	18.00	19.60
107-18-L	18.3	682	0.515	360.0	364.7	18.00	19.50
113-18-L	18.3	682	0.515	360.0	365.6	18.00	19.20
						Ave. Final MC =	19.30
102-18-L	18.3	567	0.091	360.0	362.0	16.00	16.60
208-18-L	18.3	567	0.091	360.0	361.0	16.00	16.30
120-18-L	18.3	895	0.222	360.0	361.0	16.00	16.40
202-18-L	18.3	895	0.222	360.0	360.9	19.00	16.40
232-18-L	18.3	895	0.222	360.0	361.1	16.00	16.40
132-18-L	18.3	1157	0.339	360.0	360.9	16.00	16.50
138-18-L	18.3	1157	0.339	360.0	361.7	16.00	16.60
126-18-L	18.3	1395	0.508	360.0	359.0	16.00	16.20
144-18-L	18.3	1395	0.508	360.0	358.6	16.00	16.10
244-18-L	18.3	1395	0.508	360.0	361.2	16.00	16.70
						Ave. Final MC =	16.40

Table IVa. Moisture Content (MC, wet basis) During Storage of Medium Grain (Nato) Rough Rice Samples.

Sample Code	Temperature, °C	Storage Time, h	Ave. DML, %	Sample Weight, g		Sample Moisture, %	
				Initial	Final	Initial	Final
719-35-M	35	138	0.130	218	213.2	20.00	18.30
831-35-M	35	138	0.130	218	212.9	20.00	18.20
743-35-M	35	216	0.320	218	213.0	20.00	18.30
813-35-M	35	216	0.320	218	213.2	20.00	18.40
701-35-M	35	258	0.321	218	213.1	20.00	18.40
837-35-M	35	258	0.321	218	214.2	20.00	18.80
807-35-M	35	258	0.321	218	213.7	20.00	18.60
707-35-M	35	381	0.722	218	213.7	20.00	18.90
801-35-M	35	381	0.722	218	212.2	20.00	18.30
825-35-M	35	381	0.722	218	214.8	20.00	19.30
						Ave. final MC =	18.60
704-35-M	35	228	0.119	367	361.0	18.00	17.00
746-35-M	35	228	0.119	367	360.0	18.00	16.80
710-35-M	35	327	0.220	367	361.5	18.00	17.20
716-35-M	35	327	0.220	367	360.2	18.00	16.90
804-35-M	35	327	0.220	367	362.0	18.00	17.30
722-35-M	35	424	0.336	367	363.8	18.00	17.80
740-35-M	35	424	0.336	367	361.9	18.00	17.40
816-35-M	35	468	0.467	367	362.0	18.00	17.60
840-35-M	35	468	0.467	367	362.0	18.00	17.60
						Ave. final MC =	17.30
741-35-M	35	327	0.130	357.5	359.5	16.00	16.60
835-35-M	35	327	0.130	357.5	356.0	16.00	15.70
841-35-M	35	327	0.130	357.5	356.7	16.00	15.80
723-35-M	35	638	0.345	357.5	359.3	16.00	16.70
817-35-M	35	638	0.345	357.5	357.2	16.00	16.20
847-35-M	35	663	0.433	357.5	358.2	16.00	16.50
735-35-M	35	663	0.433	357.5	360.1	16.00	16.90
						Ave. final MC =	16.30

Table IVb. Moisture Content (MC, wet basis) During Storage of Medium Grain (Nato) Rough Rice Samples

Sample Code	Temperature, °C	Storage Time, h	Ave. DML, %	Sample Weight, g		Sample Moisture, %	
				Initial	Final	Initial	Final
546-29-M	29.4	275	0.124	367.0	364.4	18.00	17.80
610-29-M	29.4	275	0.124	367.0	362.0	18.00	17.20
616-29-M	29.4	275	0.124	367.0	363.0	18.00	17.50
522-29-M	29.4	686	0.242	367.0	360.1	18.00	16.90
628-29-M	29.4	686	0.242	367.0	357.6	18.00	16.30
516-29-M	29.4	807	0.352	367.0	362.3	18.00	17.40
640-29-M	29.4	807	0.352	367.0	360.0	18.00	17.00
540-29-M	29.4	949	0.458	367.0	362.5	18.00	17.60
646-29-M	29.4	949	0.458	367.0	361.1	18.00	17.30
					Ave. final MC = 17.20		
517-29-M	29.4	326	0.094	360.0	355.5	16.00	15.00
547-29-M	29.4	326	0.094	360.0	357.8	16.00	15.60
647-29-M	29.4	326	0.094	360.0	358.1	16.00	15.70
535-29-M	29.4	901	0.223	360.0	356.7	16.00	15.40
611-29-M	29.4	901	0.223	360.0	359.5	16.00	16.10
635-29-M	29.4	901	0.223	360.0	358.7	16.00	15.90
505-29-M	29.4	1313	0.342	360.0	357.0	16.00	15.60
511-29-M	29.4	1313	0.342	360.0	356.7	16.00	15.50
605-29-M	29.4	1313	0.342	360.0	357.9	16.00	15.80
523-29-M	29.4	1662	0.492	360.0	357.3	16.00	15.80
617-29-M	29.4	1662	0.492	360.0	358.8	16.00	16.10
629-29-M	29.4	1662	0.492	360.0	359.2	16.00	16.20
					Ave. final MC = 15.70		

Table IVc. Moisture Content (MC, wet basis) During Storage of Medium Grain (Nato) Rough Rice Samples

Sample Code	Temperature, °C	Storage Time, h	Ave. DML, %	Sample Weight, g		Sample Moisture, %	
				Initial	Final	Initial	Final
325-24-M	23.9	479	0.123	312.0	314.0	20.00	20.50
301-24-M	23.9	479	0.123	312.0	312.7	20.00	20.20
307-24-M	23.9	787	0.375	312.0	311.0	20.00	19.80
419-24-M	23.9	787	0.375	312.0	307.4	20.00	18.90
337-24-M	23.9	1363	0.426	312.0	310.5	20.00	19.70
343-24-M	23.9	1363	0.426	312.0	315.3	20.00	21.00
313-24-M	23.9	1363	0.426	312.0	311.9	20.00	20.10
						Ave. final MC =	20.00
322-24-M	23.9	423	0.110	366.0	366.0	18.00	18.10
422-24-M	23.9	423	0.110	366.0	365.2	18.00	18.00
310-24-M	23.9	804	0.240	366.0	364.8	18.00	18.00
434-24-M	23.9	804	0.240	366.0	364.7	18.00	18.00
337-24-M	23.9	1071	0.297	366.0	365.7	18.00	18.30
346-24-M	23.9	1071	0.297	366.0	366.3	18.00	18.40
440-24-M	23.9	1071	0.297	366.0	367.7	18.00	18.70
316-24-M	23.9	1163	0.496	366.0	365.1	18.00	18.30
428-24-M	23.9	1163	0.496	366.0	365.0	18.00	18.20
						Ave. final MC =	18.20
311-24-M	23.9	804	0.109	360.0	358.0	16.00	15.60
323-24-M	23.9	804	0.109	360.0	358.2	16.00	15.70
435-24-M	23.9	804	0.109	360.0	358.2	16.00	15.70
347-24-M	23.9	1823	0.250	360.0	357.9	16.00	15.70
417-24-M	23.9	1823	0.250	360.0	356.7	16.00	15.40
						Ave. final MC =	15.60

Table IVd. Moisture Content (MC, wet basis) During Storage of Medium Grain (Nato) Rough Rice Samples.

Sample Code	Temperature, °C	Storage Time, h	Ave. DML, %	Sample Weight, g Initial	Sample Weight, g Final	Sample Moisture, % Initial	Sample Moisture, % Final
113-18-M	18.3	404	0.105	312.0	311.2	20.00	19.70
143-18-M	18.3	404	0.105	312.0	311.5	20.00	19.80
201-18-M	18.3	404	0.105	312.0	309.8	20.00	19.40
207-18-M	18.3	404	0.105	312.0	309.8	20.00	19.40
101-18-M	18.3	882	0.183	312.0	312.9	20.00	20.30
125-18-M	18.3	882	0.183	312.0	316.2	20.00	21.10
231-18-M	18.3	882	0.183	312.0	314.4	20.00	20.60
240-18-M	18.3	882	0.183	312.0	311.3	20.00	19.80
119-18-M	18.3	1218	0.306	312.0	311.7	20.00	20.00
137-18-M	18.3	1218	0.306	312.0	316.1	20.00	21.50
213-18-M	18.3	1218	0.306	312.0	310.5	20.00	19.70
246-18-M	18.3	1218	0.306	312.0	310.6	20.00	19.80
107-18-M	18.3	2060	0.456	312.0	308.6	20.00	19.40
131-18-M	18.3	2060	0.456	312.0	310.6	20.00	19.90
219-18-M	18.3	2060	0.456	312.0	311.1	20.00	20.00
225-18-M	18.3	2060	0.456	312.0	309.2	20.00	19.50
						Ave. final MC =	20.00
138-18-M	18.3	835	0.128	305.0	306.0	18.00	18.30
238-18-M	18.3	835	0.128	305.0	307.4	18.00	18.70
120-18-M	18.3	1218	0.228	305.0	303.5	18.00	17.90
126-18-M	18.3	1218	0.228	305.0	306.7	18.00	18.80
108-18-M	18.3	1563	0.378	305.0	302.5	18.00	17.70
144-18-M	18.3	1563	0.378	305.0	312.6	18.00	20.30
226-18-M	18.3	1563	0.378	305.0	308.4	18.00	19.20
102-18-M	18.3	2060	0.542	305.0	294.5	18.00	15.50
114-18-M	18.3	2060	0.542	305.0	309.2	18.00	19.60
232-18-M	18.3	2060	0.542	305.0	297.0	18.00	16.30
244-18-M	18.3	2060	0.542	305.0	304.0	18.00	18.20
						Ave. final MC =	18.75
117-18-M	18.3	921	0.124	360.0	364.3	16.00	17.70
229-18-M	18.3	921	0.124	360.0	362.3	16.00	17.20
141-18-M	18.3	1608	0.285	360.0	363.1	16.00	17.60
241-18-M	18.3	1608	0.285	360.0	363.3	16.00	17.40
						Ave. final MC =	17.50

Table Va. Moisture Content (MC, wet basis) During Storage of Hand-Threshed Long Grain (Arkansas-007) Rough Rice Samples

Sample Code	Temperature, °C	Storage Time,h	Ave. DML,%	Sample Weight, g Initial	Sample Weight, g Final	Sample Moisture,% Initial	Sample Moisture,% Final
819-35-H	35.0	105	0.224	312.0	310.3	20.0	19.7
831-35-H	35.0	105	0.224	312.0	310.8	20.0	19.9
828-35-H	35.0	250	0.544	312.0	310.7	20.0	20.0
846-35-H	35.0	250	0.544	312.0	311.2	20.0	20.1
837-35-H	35.0	297	0.637	312.0	310.9	20.0	20.1
843-35-H	35.0	297	0.637	312.0	310.9	20.0	20.1
822-35-H	35.0	346	0.676	312.0	309.8	20.0	20.0
834-35-H	35.0	346	0.676	312.0	309.9	20.0	20.0
840-35-H	35.0	346	0.676	312.0	310.0	20.0	20.0
						Ave. Final MC =	19.99
719-35-H	35.0	118	0.162	305.0	297.3	18.0	16.0
743-35-H	35.0	118	0.162	305.0	301.4	18.0	17.2
731-35-H	35.0	237	0.324	305.0	300.8	18.0	17.2
734-35-H	35.0	237	0.324	305.0	300.9	18.0	17.2
704-35-H	35.0	309	0.431	305.0	300.2	18.0	17.0
722-35-H	35.0	309	0.431	305.0	300.4	18.0	17.0
701-35-H	35.0	333	0.452	305.0	297.6	18.0	16.4
713-35-H	35.0	333	0.452	305.0	297.6	18.0	16.4
						Ave. Final MC =	16.80
601-35-H	35.0	507	0.197	298.0	295.6	16.0	15.6
619-35-H	35.0	507	0.197	298.0	294.4	16.0	15.2
622-35-H	35.0	507	0.197	298.0	295.2	16.0	15.5
						Ave. Final MC =	15.43
510-24-H	23.9	153	0.120	312.0	310.2	20.0	19.6
516-24-H	23.9	153	0.120	312.0	310.2	20.0	19.6
513-24-H	23.9	322	0.267	312.0	310.2	20.0	19.8
537-24-H	23.9	322	0.267	312.0	310.3	20.0	19.8
534-24-H	23.9	522	0.430	312.0	309.8	20.0	19.8
543-24-H	23.9	522	0.430	312.0	309.9	20.0	19.8
						Ave. Final MC =	19.73

Table VIb. Moisture Content (MC, wet basis) During Storage of Mechanically-Threshed Long Grain (Arkansas-007) Rough Rice Samples.

Sample Code	Temperature, °C	Storage Time,h	Ave. DML,%	Sample Weight, g Initial	Sample Weight, g Final	Sample Moisture,% Initial	Sample Moisture,% Final
811-35-C	35.0	105	0.333	312.0	310.0	20.0	19.7
814-35-C	35.0	105	0.333	312.0	310.0	20.0	19.7
829-35-C	35.0	105	0.333	312.0	310.2	20.0	19.7
844-35-C	35.0	158	0.579	312.0	309.9	20.0	19.9
817-35-C	35.0	158	0.579	312.0	310.0	20.0	19.9
805-35-C	35.0	250	1.020	312.0	308.5	20.0	19.9
835-35-C	35.0	250	1.020	312.0	308.9	20.0	20.0
						Ave. Final MC =	19.83
714-35-C	35.0	141	0.141	305.0	300.7	18.0	17.0
711-35-C	35.0	141	0.141	305.0	301.0	18.0	17.1
705-35-C	35.0	237	0.297	305.0	300.7	18.0	17.1
747-35-C	35.0	237	0.297	305.0	301.9	18.0	17.4
717-35-C	35.0	309	0.330	305.0	300.7	18.0	17.2
726-35-C	35.0	309	0.330	305.0	300.7	18.0	17.2
702-35-C	35.0	333	0.549	305.0	299.7	18.0	17.0
720-35-C	35.0	333	0.549	305.0	299.1	18.0	16.9
						Ave. Final MC =	17.11
602-35-C	35.0	507	0.097	298.0	297.1	16.0	15.8
611-35-C	35.0	507	0.097	298.0	296.8	16.0	15.7
						Ave. Final MC =	15.75
526-24-C	23.9	105	0.180	312.0	310.3	20.0	19.7
529-24-C	23.9	105	0.180	312.0	310.5	20.0	19.8
508-24-C	23.9	131	0.235	312.0	310.3	20.0	19.7
547-24-C	23.9	131	0.235	312.0	310.2	20.0	19.7
514-24-C	23.9	251	0.402	312.0	309.9	20.0	19.8
517-24-C	23.9	251	0.402	312.0	310.0	20.0	19.8
511-24-C	23.9	321	0.592	312.0	309.5	20.0	19.8
535-24-C	23.9	321	0.592	312.0	309.3	20.0	19.8
						Ave. Final MC =	19.80

APPENDIX B

DRY MATTER LOSS

Table VIa. Carbon Dioxide (Gram) Evolved by Long Grain (Newrex) Rough Rice During Storage at 35.0°C and 19.9% Moisture.

Time (h)	Sample code											Ave. CO_2 [a]	DML (%) [b]
	704	710	716	722	728	734	746	822	828	834	840		
43	0.248	0.074	0.422	0.576	0.729	0.397	0.317	0.298	0.552	0.272	0.235	0.330	0.128
66	0.544	0.288	0.977	c/	c/	0.822	0.578	0.646	0.771	0.400	0.538	0.549	0.213
89	0.712	0.717	c/	-	-	1.233	0.938	1.030	c/	0.770	0.857	0.833	0.324
114	1.351	c/	-	-	-	c/	1.289	c/	-	1.412	1.346	1.350	0.525

a/ Average weight of carbon dioxide (g) evolved from 175 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide by using the factor of 1.47 g CO_2 per gram dry weight of sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIb. Carbon Dioxide (Gram) Evolved by Long Grain (Newrex) Rough Rice During Storage at 35.0°C and 17.1% Moisture.

Time (h)	Sample code									Ave. CO_2 [a]	DML (%) [b]
	713	731	737	743	801	807	825	837	843		
22	0.060	0.191	0.094	0.049	0.076	0.061	0.139	0.045	0.075	0.088	0.020
95	0.350	0.500	0.536	0.510	0.341	0.334	0.679	0.391	0.143	0.420	0.095
136	0.711	1.130	1.089	0.968	0.456	0.464	1.201	0.842	0.499	0.813	0.184
179	1.193	c/	1.630	1.997	c/	c/	1.695	1.222	0.990	1.344	0.305
228	c/	-	2.264	-	-	-	2.575	1.913	c/	2.251	0.510

a/ Average weight of carbon dioxide (g) evolved from 300 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIc. Carbon Dioxide (Gram) Evolved by Long Grain (Newrex) Rough Rice During Storage at 35.0°C and 15.7% Moisture.

Time	Sample code											Ave. CO_2 [a]	DML (%) [b]
	702	708	714	720	726	732	738	744	814	826	832		
22	0.103	0.103	0.085	0.096	0.127	0.136	0.049	0.123	0.103	0.230	0.102	0.116	0.027
94	0.353	0.248	0.243	0.153	0.248	0.226	0.109	0.276	0.320	0.257	0.126	0.224	0.051
137	0.457	0.371	0.391	0.332	0.381	0.407	0.186	0.414	0.437	0.318	0.226	0.352	0.080
180	0.635	0.559	0.557	0.506	0.566	0.680	0.283	0.650	0.618	0.477	0.452	0.541	0.124
228	0.867	0.845	0.667	0.753	0.798	c/	0.521	c/	c/	0.581	0.809	0.749	0.171
254	1.059	1.064	0.723	0.955	1.122	-	0.752	-	-	0.884	1.013	0.934	0.213
278	1.294	1.333	0.905	1.240	1.268	-	1.080	-	-	1.050	1.360	1.191	0.272
303	c/	1.673	c/	1.593	1.601	-	1.383	-	-	1.279	1.794	1.554	0.355
327	-	1.967	-	2.012	1.784	-	1.750	-	-	1.509	1.844	1.811	0.413
351	-	2.109	-	2.270	c/	-	c/	-	-	c/	2.599	2.326	0.531

a/ Average weight of carbon dioxide (g) evolved from 300 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the the factor 1.47 g CO /g dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernel measurement.

Table VId. Carbon Dioxide (Gram) Evolved by Long Grain (Newrex) Rough Rice During Storage at 29.4°C and 20.0% Moisture.

Time (h)	sample code											Ave. CO_2 [a/]	DML (%) [b/]
	510	516	528	534	540	610	616	622	628	640	646		
36	0.136	0.166	0.211	0.135	0.306	0.178	0.156	0.135	0.152	0.272	0.459	0.210	0.057
61	0.233	0.266	0.294	0.228	0.398	0.293	0.248	0.345	0.262	0.383	0.544	0.317	0.860
84	0.347	0.375	0.397	0.334	0.483	0.439	0.359	0.468	0.401	0.518	0.674	0.436	0.119
108	0.587	0.588	0.600	0.532	0.692	0.686	0.554	0.708	0.626	0.739	0.857	0.651	0.177
181	c/	c/	1.476	2.086	1.703	2.005	c/	1.766	1.607	1.912	1.227	1.723	0.469
201	-	-	c/	2.337	c/	2.121	-	c/	c/	2.638	c/	2.363	0.644

a/ Average weight of carbon dioxide (g) evolved from 250 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIe. Carbon Dioxide (Gram) Evolved by Long Grain (Newrex) Rough Rice During Storage at 29.4°C and 18.4% Moisture.

Time (h)	Sample code											Ave. CO_2 [a]	DML (%) [b]
	507	513	519	525	531	543	601	607	619	631	637		
95	0.239	0.596	0.196	0.344	0.609	0.304	0.381	0.639	0.187	0.729	0.432	0.405	0.092
136	0.429	1.089	0.412	0.583	1.071	0.931	0.886	1.081	0.288	1.245	0.763	0.759	0.172
179	0.625	c/	0.645	0.864	1.512	1.304	c/	1.469	0.414	1.652	1.152	1.007	0.228
228	0.897	-	c/	1.097	1.917	1.581	-	1.781	c/	2.101	c/	1.417	0.321
253	c/	-	-	1.296	c/	1.691	-	2.108	-	c/	-	1.698	0.385
275	-	-	-	1.443	-	1.860	-	2.292	-	-	-	1.865	0.423
302	-	-	-	c/	-	2.053	-	2.398	-	-	-	2.226	0.505

a/ Average weight of carbon dioxide (g) evolved from 300 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIf. Carbon Dioxide (Gram) Evolved by Long Grain (Newrex) Rough Rice During Storage at 29.4°C and 15.7% Moisture Content

Time (h)	Sample code 502	508	514	526	532	538	544	608	626	632	638	644	Ave. CO_2 a/	DML (%) b/
95	0.222	0.106	0.114	0.163	0.204	0.152	0.165	0.304	0.302	0.235	0.137	0.190	0.191	0.043
136	0.320	0.224	0.181	0.220	0.287	0.300	0.316	0.388	0.430	0.315	0.325	0.256	0.297	0.067
179	0.427	0.340	0.262	0.314	0.378	0.433	0.428	0.481	0.548	0.435	0.463	0.356	0.405	0.092
228	0.509	0.458	0.362	0.374	0.468	0.530	0.538	0.589	0.689	0.564	0.632	0.472	0.515	0.117
253	0.589	0.505	0.418	0.442	0.547	0.619	0.602	0.653	0.778	0.641	0.703	0.552	0.587	0.133
275	0.632	0.535	0.466	0.480	0.606	0.686	0.656	0.705	0.862	0.713	0.843	0.619	0.655	0.148
302	0.688	0.639	c/	c/	0.665	0.745	0.709	c/	0.976	0.801	0.984	0.697	0.767	0.174
326	0.735	0.691	-	-	0.715	0.788	0.756	-	1.073	0.876	1.107	0.753	0.833	0.189
352	0.768	0.762	-	-	0.780	0.826	0.811	-	1.123	0.982	1.311	0.857	0.913	0.207
377	0.835	0.826	-	-	0.841	0.849	0.858	-	1.351	1.093	1.523	0.970	1.016	0.230
403	0.884	0.891	-	-	0.899	0.902	0.910	-	1.524	1.216	1.777	1.076	1.122	0.245
425	0.927	0.952	-	-	0.955	0.920	0.957	-	1.688	1.338	1.901	1.198	1.204	0.273
447	0.967	1.009	-	-	1.009	c/	c/	-	1.854	1.465	2.026	c/	1.385	0.314
469	1.011	1.068	-	-	1.055	-	-	-	1.977	1.624	2.290	-	1.689	0.383
550	1.181	1.308	-	-	1.285	-	-	-	2.052	2.325	2.587	-	1.789	0.405
588	c/	1.424	-	-	1.377	-	-	-	c/	2.642	c/	-	1.814	0.414
618	-	1.528	-	-	1.441	-	-	-	-	2.865	-	-	1.945	0.444
640	-	1.609	-	-	1.500	-	-	-	-	3.011	-	-	2.040	0.466

a/ Average weight of carbon dioxide (g) evolved from 300 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIg. Carbon Dioxide (Gram) Evolved by Long Grain (Newrex) Rough Rice During Storage at 23.9°C and 19.4% Moisture.

Time (h)	Sample code												Ave.[a/] CO_2	DML[b/] (%)
	304	322	328	334	340	404	410	422	428	434	440	446		
47	0.169	0.200	0.139	0.124	0.162	0.145	0.171	0.176	0.181	0.131	0.197	0.160	0.163	0.442
97	0.344	0.376	0.272	0.206	0.343	0.309	0.332	0.370	0.379	0.285	0.410	0.357	0.332	0.090
117	0.429	0.455	0.331	0.248	0.410	0.389	0.417	0.456	0.466	0.346	0.502	0.441	0.406	0.111
140	0.530	0.552	0.403	0.286	0.500	0.472	0.503	0.553	0.563	0.416	0.604	0.531	0.493	0.134
163	0.657	0.680	0.498	0.376	_c/	0.578	0.609	0.670	_c/	0.509	_c/	0.660	0.582	0.158
236	1.148	1.177	0.845	0.731	-	1.001	1.112	1.244	-	0.889	-	1.168	1.035	0.282
264	1.192	_c/	0.960	0.858	-	1.195	1.293	1.481	-	1.045	-	_c/	1.146	0.312
289	1.280	-	1.070	0.969	-	1.377	1.447	1.665	-	1.125	-	-	1.276	0.347
310	1.560	-	1.164	1.016	-	1.479	1.541	1.793	-	1.190	-	-	1.392	0.379
357	_c/	-	_c/	1.186	-	_c/	1.790	2.227	-	_c/	-	-	1.734	0.472
403	-	-	-	1.438	-	-	2.047	2.484	-	-	-	-	1.990	0.541
453	-	-	-	1.812	-	-	2.368	2.668	-	-	-	-	2.283	0.621

a/ Average weight of carbon dioxide (g) evolved from 250 g dry weightof the sample.

b/ Equivalent dry matter loss (%), calculated from the average weightof carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kerels measurements.

Table VIh. Carbon Dioxide (Gram) Evolved by Long Grain (Newrex) Rough Rice During Storage at 23.9°C and 19.8% Moisture.

Time (h)	Sample code 301	307	313	319	325	331	343	407	413	419	425	431	437	Ave. CO_2 a/	DML (%) b/
113	0.570	0.179	0.611	0.477	0.589	0.534	0.560	0.317	0.476	0.403	0.315	0.328	0.463	0.448	0.102
156	0.845	0.430	0.916	0.715	0.812	0.751	0.827	0.480	0.686	0.554	0.615	0.555	0.655	0.680	0.155
206	0.879	0.744	0.946	1.027	1.194	1.066	1.177	0.793	1.021	0.698	0.833	0.760	0.977	0.932	0.211
233	c/	0.990	c/	1.280	1.465	1.356	1.449	0.917	1.255	c/	1.013	0.967	1.213	1.216	0.276
258	-	1.151	-	c/	1.687	c/	1.645	0.925	1.433	-	c/	1.038	1.326	1.316	0.298
302	-	1.500	-	-	2.164	-	2.124	1.376	1.841	-	-	1.288	1.695	1.695	0.384
323	-	1.613	-	-	2.397	-	2.364	1.470	2.027	-	-	1.425	1.705	1.857	0.421
351	-	c/	-	-	2.673	-	2.639	-	2.178	-	-	c/	c/	2.497	0.566

a/ Average weight of carbon dioxide (g) evolved from 300 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIi. Carbon Dioxide (Gram) Evolved by lLng Grain (Newrex) Rough Rice During Storage at 23.9^{o}C and 15.7% Moisture

Time (h)	Sample code 302	308	314	320	402	408	414	426	432	444	Ave. CO_2 [a/]	DML (%) [b/]
113	0.201	0.182	0.153	0.180	0.301	0.174	0.152	0.105	0.120	0.158	0.172	0.039
156	0.249	0.237	0.183	0.211	0.308	0.160	0.161	0.113	0.143	0.172	0.194	0.044
206	0.299	0.305	0.251	0.303	0.360	0.192	0.254	0.153	0.209	0.242	0.257	0.058
238	0.316	0.381	0.204	0.370	0.395	0.212	0.303	0.180	0.272	0.283	0.302	0.068
258	0.331	0.424	0.342	0.403	0.440	0.250	0.320	0.210	0.307	0.290	0.332	0.075
302	0.370	0.517	0.408	0.497	0.484	0.279	0.417	0.264	0.398	0.360	0.399	0.091
323	0.380	0.548	0.437	0.535	0.502	0.295	0.456	0.297	0.425	0.386	0.426	0.097
351	0.391	0.601	0.472	0.570	0.520	0.310	0.504	0.320	0.470	0.422	0.458	0.104
399	_c/	0.687	0.536	0.673	0.563	_c/	_c/	0.356	0.551	0.482	0.550	0.125
446	_	0.782	0.602	0.766	0.616	_	_	0.391	0.661	0.545	0.623	0.141
469	_	0.818	0.630	0.800	0.640	_	_	0.406	0.694	0.566	0.651	0.148
550	_	0.995	0.710	0.974	0.743	_	_	0.467	0.924	0.674	0.784	0.178
570	_	1.036	0.793	1.014	0.764	_	_	0.481	0.982	0.700	0.824	0.184
613	_	1.136	0.841	1.113	0.824	_	_	0.521	1.138	0.768	0.906	0.205
661	_	1.198	0.908	1.171	0.857	_	_	0.540	1.230	0.820	0.961	0.218
686	_	1.316	0.988	1.286	0.923	_	_	0.578	1.433	0.909	1.062	0.241
764	_	1.501	1.118	1.467	_c/	_	_	_c/	_c/	1.062	1.287	0.292
782	_	1.546	1.147	1.510	_	_	_	_	_	1.095	1.325	0.300
804	_	1.605	1.185	1.562	_	_	_	_	_	1.138	1.373	0.311
832	_	1.681	1.239	1.635	_	_	_	_	_	1.203	1.439	0.326
857	_	1.750	1.287	1.703	_	_	_	_	_	1.266	1.502	0.340
899	_	1.813	1.347	1.770	_	_	_	_	_	1.383	1.578	0.358
927	_	1.898	1.425	1.890	_	_	_	_	_	1.464	1.669	0.379
1030	_	2.175	1.636	_c/	_	_	_	_	_	_c/	1.906	0.432
1071	_	2.292	1.721	_	_	_	_	_	_	_	2.006	0.455
1096	_	2.373	1.775	_	_	_	_	_	_	_	2.074	0.470
1114	_	2.430	1.814	_	_	_	_	_	_	_	2.122	0.481

a/ Average weight of carbon dioxide (g) evolved from 300 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2/g dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIj. Carbon Dioxide (Gram) Evolved by Long Grain (Newrex) Rough Rice During Storage at 18.3°C and 19.5% Moisture.

Time (h)	Sample code												Ave. CO_2 [a/]	DML (%) [b/]
	110	116	122	128	140	146	204	210	216	234	240	246		
49	0.070	0.068	0.065	0.084	0.055	0.160	0.099	0.114	0.106	0.096	0.093	0.122	0.094	0.026
100	0.159	0.127	0.130	0.176	0.099	0.306	0.166	0.232	0.191	0.193	0.172	0.253	0.183	0.050
140	0.238	0.184	0.190	0.268	0.131	0.468	0.236	0.355	0.280	0.297	0.207	0.375	0.269	0.073
167	0.176	0.213	0.217	0.313	0.156	0.544	0.272	0.417	0.322	0.349	0.280	0.458	0.310	0.084
236	0.388	0.382	0.445	0.576	0.303	0.934	0.495	0.788	0.562	0.685	0.502	0.920	0.582	0.158
289	0.620	0.475	0.558	0.730	0.384	_c/	0.652	_c/	0.762	0.783	0.666	1.235	0.686	0.187
355	0.802	0.589	0.703	0.944	0.458	–	0.796	–	0.937	0.997	0.790	1.562	0.857	0.233
404	0.872	0.684	0.787	1.138	0.513	–	0.925	–	1.078	1.140	0.910	1.792	0.984	0.268
428	1.057	0.726	0.817	1.236	0.536	–	0.989	–	1.142	1.202	0.942	1.892	1.056	0.287
476	_c/	_c/	0.917	1.426	0.603	–	_c/	–	1.286	1.351	1.001	2.132	1.244	0.338
499	–	–	0.942	1.489	0.673	–	–	–	1.361	1.433	1.022	2.369	1.327	0.361
596	–	–	1.107	_c/	0.984	–	–	–	_c/	1.832	_c/	2.990	1.728	0.470
643	–	–	1.184	–	1.284	–	–	–	–	2.177	–	3.544	2.047	0.557
668	–	–	1.210	–	1.363	–	–	–	–	2.288	–	3.687	2.137	0.581

a/ Average weight of carbon dioxide (g) evolved from 250 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIk. Carbon Dioxide (Gram) Evolved by Long Grain (Newrex) Rough Rice During Storage at 18.3°C and 19.3% Moisture.

Time (h)	Sample code 101	107	113	119	125	131	143	201	213	231	Ave[a] CO_2	DML[b] (%)
113	0.161	0.197	0.235	0.092	0.290	0.110	0.275	0.230	0.132	0.382	0.210	0.048
156	0.247	0.250	0.337	0.137	0.399	0.161	0.375	0.330	0.196	0.494	0.293	0.066
206	0.347	0.335	0.447	0.191	0.526	0.221	0.484	0.444	0.274	0.609	0.388	0.088
252	0.445	0.429	0.568	0.253	0.666	0.292	0.589	12574	0.368	0.755	0.494	0.112
300	0.563	0.537	0.702	0.317	0.838	0.388	0.682	0.701	0.472	0.918	0.631	0.143
348	0.693	0.649	0.860	_c/	1.025	0.497	_c/	_c/	0.573	1.086	0.769	0.174
398	0.865	0.786	1.049	-	1.251	0.611	-	-	0.708	1.286	0.937	0.212
422	0.958	0.863	1.146	-	1.373	0.650	-	-	0.774	1.396	1.023	0.232
445	1.148	1.031	1.335	-	_c/	0.822	-	-	0.916	_c/	1.050	0.240
466	1.224	1.093	1.412	-	-	0.867	-	-	0.947	-	1.109	0.253
547	1.413	1.398	1.814	-	-	1.062	-	-	1.066	-	1.351	0.308
567	1.710	1.473	1.913	-	-	1.108	-	-	1.097	-	1.460	0.333
609	1.962	1.660	2.155	-	-	1.248	-	-	1.191	-	1.643	0.375
635	2.114	1.778	2.305	-	-	1.329	-	-	1.209	-	1.747	0.399
659	2.264	1.896	2.456	-	-	1.411	-	-	1.255	-	1.856	0.424
682	2.316	2.013	2.490	-	-	1.484	-	-	1.295	-	1.920	0.438

a/ Average weight of carbon dioxide (g) evolved from 300 g dry weight of the sample.

b/ Equivalent dry matter loss (%) calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VI1. Carbon dioxide (Gram) Evolved by Long Grain (Newrex) Rough Rice During Storage at 18.3°C and 16.4% Moisture.

Time (h)	Sample code 102	108	120	126	132	138	144	202	208	226	232	244	Ave. CO_2 [a]	DML (%) [b]
113	0.043	0.027	0.072	0.072	0.080	0.090	0.074	0.096	0.184	0.066	0.105	0.114	0.085	0.019
156	0.062	0.038	0.092	0.100	0.110	0.123	0.103	0.124	0.211	0.077	0.131	0.152	0.110	0.025
206	0.090	0.053	0.123	0.137	0.145	0.162	0.136	0.155	0.257	0.085	0.161	0.088	0.140	0.032
252	0.171	0.021	0.220	0.232	0.238	0.260	0.234	0.236	0.356	0.150	0.255	0.283	0.230	0.052
300	0.208	0.137	0.265	0.287	0.287	0.317	0.290	0.269	0.409	0.166	0.299	0.333	0.272	0.062
348	0.240	0.150	0.304	0.339	0.332	0.362	0.290	0.269	0.409	0.179	0.345	0.382	0.311	0.070
398	0.273	0.168	0.344	0.395	0.380	0.430	0.397	0.345	0.507	0.190	0.385	0.434	0.354	0.078
445	0.311	0.183	0.389	0.455	0.430	0.489	0.456	0.389	0.563	0.206	0.406	0.490	0.397	0.090
567	0.409	0.230	0.514	0.601	0.550	0.646	0.606	0.493	0.711	0.257	0.599	0.633	0.501	0.118
609	_c/	_c/	0.572	0.665	0.601	0.710	0.670	0.533	_c/	_c/	0.686	0.688	0.653	0.148
635	_	_	0.604	0.701	0.631	0.747	0.708	0.559	_	_	0.735	0.721	0.676	0.153
659	_	_	0.642	0.730	0.665	0.788	0.751	0.584	_	_	0.787	0.758	0.713	0.162
761	_	_	0.755	0.858	0.774	0.920	0.882	0.660	_	_	0.975	0.870	0.837	0.190
801	_	_	0.795	0.904	0.808	0.958	0.922	0.700	_	_	1.015	0.910	0.877	0.199
829	_	_	0.844	0.959	0.852	1.015	0.974	0.735	_	_	1.081	0.954	0.927	0.212
851	_	_	0.920	1.037	0.921	1.093	1.052	0.791	_	_	1.152	1.022	0.999	0.228
895	_	_	0.950	1.070	0.943	1.124	1.086	0.794	_	_	1.200	1.050	1.026	0.234
1039	_	_	_c/	1.313	1.176	1.380	1.357	_c/	_	_	_c/	1.289	1.303	0.295
1086	_	_	_	1.389	1.245	1.456	1.436	_	_	_	_	1.366	1.378	0.313
1135	_	_	_	1.485	1.348	1.550	1.536	_	_	_	_	1.462	1.476	0.335
1157	_	_	_	1.530	1.402	1.593	1.584	_	_	_	_	1.505	1.523	0.345
1306	_	_	_	1.937	_c/	_c/	2.040	_	_	_	_	1.931	1.969	0.447
1346	_	_	_	2.020	_	_	2.145	_	_	_	_	2.028	2.064	0.468
1395	_	_	_	2.118	_	_	2.298	_	_	_	_	2.183	2.200	0.499

a/ Average weight of carbon dioxide (g) evolved from 300 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide by using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIIa. Carbon Dioxide (Gram) Evolved by Medium Grain (Nato) Rough Rice During Storage at 35°C and 20.0% Moisture.

Time (h)	Sample code										Ave.[a] CO_2	DML[b] (%)
	701	707	719	743	801	807	813	825	831	837		
43	0.118	0.103	0.112	0.128	0.078	0.057	0.094	0.066	0.042	0.080	0.088	0.034
66	0.208	0.175	0.178	0.162	0.112	0.131	0.125	0.091	0.116	0.117	0.141	0.055
89	0.268	0.228	0.253	0.276	0.181	0.115	0.149	0.101	0.214	0.162	0.195	0.076
114	0.338	0.289	0.346	0.346	0.248	0.164	0.173	0.114	0.282	0.214	0.251	0.098
138	0.425	0.357	0.430	0.405	0.355	0.254	0.264	0.148	0.368	0.308	0.331	0.129
161	0.471	0.428	-[c]	0.484	0.441	0.334	0.353	0.188	-[c]	0.353	0.382	0.148
216	0.540	0.525	-	0.657	0.625	0.508	0.989	0.725	-	0.608	0.647	0.251
240	0.894	0.762	-	-[c]	0.798	0.705	-[c]	1.117	-	0.746	0.837	0.325
258	0.979	0.812	-	-	0.858	0.746	-	1.246	-	0.752	0.899	0.349
281	-[c]	0.878	-	-	0.918	-[c]	-	1.522	-	-[c]	1.106	0.430
305	-	0.921	-	-	0.943	-	-	1.549	-	-	1.138	0.422
329	-	0.946	-	-	0.986	-	-	1.842	-	-	1.256	0.489
353	-	0.973	-	-	1.048	-	-	2.078	-	-	1.366	0.531
381	-	1.098	-	-	1.311	-	-	3.163	-	-	1.857	0.722

a/ Average weight of carbon dioxide (g) evolved from 175 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIIb. Carbon Dioxide (Gram) Evolved by Medium Grain (Nato) Rough Rice During Storage at 35.0°C and 17.3% Moisture.

Time	Sample code									a/	b/
(h)	704	710	716	722	740	746	804	816	840	Ave. CO_2	DML (%)
22	0.010	0.001	0.036	0.020	0.069	0.019	0.129	0.036	0.071	0.056	0.013
94	0.217	0.192	0.192	0.114	0.099	0.181	0.189	0.099	0.164	0.164	0.037
137	0.321	0.368	0.345	0.245	0.287	0.292	0.275	0.328	0.313	0.308	0.070
180	0.437	0.493	0.502	0.373	0.408	0.414	0.435	0.536	0.485	0.454	0.103
228	0.536	0.669	0.568	0.496	0.609	0.516	0.558	0.734	0.659	0.594	0.135
254	c/	0.752	0.667	0.575	0.700	c/	0.679	0.851	0.756	0.714	0.162
278	–	0.823	0.718	0.651	0.802	–	0.791	0.985	0.875	0.811	0.184
303	–	0.922	0.790	0.736	0.909	–	0.899	1.103	0.970	0.908	0.206
327	–	1.045	0.875	0.827	1.027	–	0.989	1.239	1.068	1.014	0.230
351	–	c/	c/	0.917	1.144	–	c/	1.375	1.164	1.160	0.253
376	–	–	–	1.026	1.254	–	–	1.532	1.287	1.275	0.290
401	–	–	–	1.142	1.549	–	–	1.709	1.376	1.444	0.327
424	–	–	–	1.272	1.694	–	–	1.880	1.548	1.600	0.363
445	–	–	–	c/	c/	–	–	2.074	1.643	1.859	0.422
469	–	–	–	–	–	–	–	2.319	1.800	2.060	0.467

a/ Average weight of carbon dioxied (g) evolved from 300 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIIc. Carbon Dioxide Evolved by Medium Grain (Nato) Rough Rice During Storage at 35°C and 16.3% Moisture.

Time (h)	Sample code 717	723	735	741	817	835	841	847	Ave[a/] CO_2	DML[b/] (%)
22	0.001	0.033	0.034	0.015	0.115	0.014	0.014	0.060	0.035	0.008
94	0.082	0.210	0.126	0.077	0.262	0.082	0.087	0.208	0.147	0.035
137	0.138	0.354	0.274	0.183	0.387	0.141	0.165	0.363	0.251	0.057
180	0.203	0.451	0.373	0.247	0.475	0.208	0.250	0.451	0.341	0.077
228	0.308	0.584	0.519	0.358	0.589	0.295	0.345	0.569	0.446	0.101
254	0.369	0.650	0.560	0.408	0.662	0.340	0.395	0.641	0.503	0.114
278	0.463	0.725	0.662	0.489	0.786	0.375	0.429	0.772	0.588	0.133
303	0.537	0.749	0.681	0.579	0.802	0.479	0.540	0.792	0.645	0.146
327	0.555	0.792	0.737	0.629	0.842	0.519	0.590	0.832	0.688	0.156
357	_c/	0.800	0.778	_c/	0.867	_c/	_c/	0.878	0.831	0.188
376	-	0.856	0.780	-	0.865	-	-	0.884	0.845	0.192
401	-	0.900	0.830	-	0.910	-	-	0.940	0.895	0.203
424	-	0.972	0.884	-	0.953	-	-	0.990	0.950	0.215
445	-	1.014	0.921	-	0.995	-	-	1.042	0.993	0.225
468	-	1.055	0.950	-	1.042	-	-	1.094	1.035	0.235
549	-	1.267	1.196	-	1.176	-	-	1.406	1.261	0.286
570	-	1.323	1.290	-	1.232	-	-	1.486	1.333	0.302
588	-	1.370	1.361	-	1.303	-	-	1.594	1.407	0.319
616	-	1.447	1.492	-	1.426	-	-	1.772	1.534	0.348
638	-	1.513	1.611	-	1.532	-	-	1.942	1.650	0.374
663	-	_c/	1.759	-	_c/	-	-	2.156	1.908	0.433

a/
Average weight of carbon dioxide (g) evolved from 300 g dry weight of the sample.

b/
Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor 1.47 g CO_2 /g dry weight of the sample.

c/
Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIId. Carbon Dioxide (Gram) Evolved by Medium Grain (Nato) Rough Rice During Storage at and 29.4°C and 20.0% Moisture.

Time (h)	Sample code										Ave. CO_2 [a/]	DML (%) [b/]
	504	510	522	534	540	546	610	622	628	646		
36	0.431	0.257	0.499	0.371	0.410	0.520	0.434	0.511	0.316	0.183	0.393	0.107
61	0.677	0.419	0.594	0.425	0.636	0.674	0.562	0.735	0.358	0.260	0.533	0.145
84	0.879	0.562	0.630	0.452	0.827	0.808	0.686	0.947	0.384	0.326	0.650	0.177
108	c/	c/	0.843	0.505	1.166	1.063	c/	1.306	0.468	0.516	0.838	0.228
181	-	-	0.984	0.635	c/	c/	-	c/	0.864	0.993	0.869	0.236
201	-	-	1.848	1.154	-	-	-	-	1.216	1.350	1.392	0.379
226	-	-	2.562	1.435	-	-	-	-	1.397	1.532	1.732	0.471
248	-	-	3.070	c/	-	-	-	-	1.533	c/	c/	0.626
273	-	-	3.615	-	-	-	-	-	1.688	-	-	0.721

a/ Average weight of carbon dioxide (g) evolved from 250 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIIe. Carbon Dioxide (Gram) Evolved by Medium Grain (Nato) Rough Rice During Storage at 29.4°C and 17.2% Moisture.

Time (h)	Sample code 516	522	528	534	540	546	610	616	640	646	Ave. CO_2 [a/]	DML (%) [b/]
95	0.101	0.232	0.219	0.139	0.128	0.129	0.299	0.273	0.678	0.089	0.168	0.038
136	0.198	0.304	0.261	0.178	0.188	0.255	0.330	0.320	0.254	0.222	0.251	0.057
179	0.286	0.373	0.318	0.232	0.258	0.355	0.411	0.391	0.360	0.324	0.331	0.075
228	0.375	0.447	0.372	0.285	0.343	0.449	0.453	0.503	0.447	0.427	0.410	0.093
253	0.422	0.493	0.396	0.314	0.393	0.494	0.473	0.550	0.470	0.447	0.445	0.101
275	0.466	0.526	0.412	0.337	0.436	0.555	0.491	0.593	0.530	0.501	0.485	0.110
302	0.558	0.603	0.460	c/	0.527	c/	c/	c/	0.608	0.605	0.560	0.127
326	0.590	0.626	0.466	–	0.544	–	–	–	0.632	0.636	0.582	0.132
377	0.704	0.706	0.508	–	0.674	–	–	–	0.728	0.754	0.679	0.154
403	0.773	0.786	0.551	–	0.746	–	–	–	0.789	0.826	0.741	0.168
425	0.812	0.782	0.566	–	0.788	–	–	–	0.819	0.863	0.772	0.175
447	0.859	0.816	0.590	–	0.831	–	–	–	0.859	0.913	0.811	0.184
469	0.865	0.803	0.570	–	0.830	–	–	–	0.848	0.897	0.803	0.182
550	0.995	0.971	0.709	–	1.044	–	–	–	1.051	1.130	0.983	0.223
588	1.189	1.038	0.775	–	1.149	–	–	–	1.138	1.220	1.085	0.246
618	1.272	1.094	0.809	–	1.240	–	–	–	1.209	1.308	1.155	0.262
640	1.337	1.140	0.847	–	1.316	–	–	–	1.264	1.374	1.212	0.275
664	1.399	1.199	0.879	–	1.387	–	–	–	1.322	1.436	1.270	0.288
686	1.451	1.231	0.903	–	1.447	–	–	–	1.365	1.489	1.314	0.298
765	1.524	c/	c/	–	1.545	–	–	–	1.304	1.572	1.486	0.337
783	1.577	–	–	–	1.604	–	–	–	1.449	1.631	1.566	0.355
807	1.628	–	–	–	1.658	–	–	–	1.485	1.685	1.614	0.366
834	c/	–	–	–	1.740	–	–	–	c/	1.761	1.751	0.397
858	–	–	–	–	1.814	–	–	–	–	1.829	1.821	0.413
901	–	–	–	–	1.939	–	–	–	–	1.960	1.949	0.442
929	–	–	–	–	1.956	–	–	–	–	2.048	2.002	0.454
949	–	–	–	–	1.951	–	–	–	–	2.089	2.020	0.458

a/ Average weight of carbon dioxide (g) evolved from 300 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIIf. Carbon Dioxide (Gram) Evolved by Medium Grain (Nato) Rough Rice During Storage at 29.4°C and 15.7% Moisture.

Time (h)	Sample code 505	511	517	523	535	547	605	611	617	623	629	635	647	Ave. CO_2 [a]	DML [b] (%)
95	0.142	0.149	0.097	0.076	0.113	0.087	0.195	0.002	0.187	0.099	0.097	0.005	0.129	0.106	0.024
136	0.208	0.222	0.172	0.155	0.172	0.143	0.259	0.108	0.275	0.106	0.149	0.158	0.280	0.185	0.042
179	0.289	0.301	0.232	0.223	0.263	0.208	0.324	0.216	0.352	0.120	0.224	0.217	0.350	0.256	0.058
228	0.355	0.361	0.275	0.277	0.324	0.274	0.373	0.285	0.414	0.127	0.280	0.260	0.404	0.309	0.070
253	0.389	0.398	0.311	0.324	0.334	0.308	0.410	0.327	0.457	0.148	0.323	0.292	0.447	0.344	0.078
275	0.425	0.421	0.333	0.355	0.373	0.335	0.427	0.361	0.488	0.157	0.352	0.314	0.477	0.370	0.084
302	0.460	0.463	0.343	0.393	0.408	0.364	0.453	0.405	0.526	0.165	0.387	0.341	0.510	0.401	0.091
326	0.475	0.475	0.342	0.415	0.432	0.377	0.467	0.411	0.546	0.162	0.401	0.351	0.529	0.415	0.094
377	0.498	0.506	c/	0.442	0.451	c/	0.484	0.463	0.574	c/	0.425	0.362	c/	0.467	0.106
403	0.521	0.506	-	0.466	0.474	-	0.506	0.496	0.603	-	0.451	0.381	-	0.489	0.111
425	0.543	0.547	-	0.487	0.500	-	0.527	0.528	0.634	-	0.477	0.404	-	0.516	0.117
447	0.590	0.587	-	0.544	0.546	-	0.575	0.581	0.686	-	0.524	0.447	-	0.564	0.128
550	0.630	0.622	-	0.607	0.598	-	0.651	0.676	0.697	-	0.581	0.493	-	0.617	0.140
588	0.658	0.648	-	0.638	0.599	-	0.687	0.710	-	-	0.620	0.519	-	0.635	0.144
618	0.683	0.671	-	0.665	0.654	-	0.708	0.753	-	-	0.641	0.550	-	0.666	0.151
640	0.709	0.694	-	0.692	0.679	-	0.741	0.792	0.722	-	0.671	0.573	-	0.697	0.158
664	0.777	0.763	-	0.764	0.747	-	0.819	0.872	0.805	-	0.750	0.650	-	0.772	0.175
686	0.792	0.780	-	0.783	0.759	-	0.839	0.887	0.830	-	0.767	0.667	-	0.789	0.179
765	0.831	0.814	-	0.805	0.801	-	0.911	0.976	0.907	-	0.823	0.709	-	0.842	0.191
783	0.867	0.848	-	0.865	0.834	-	0.949	1.023	0.953	-	0.858	0.742	-	0.882	0.200
807	0.873	0.853	-	0.878	0.843	-	0.966	1.046	0.975	-	0.869	0.752	-	0.895	0.203
834	0.903	0.882	-	0.912	0.873	-	1.005	1.094	1.020	-	0.901	0.784	-	0.931	0.211
858	0.921	0.896	-	0.930	0.891	-	1.034	1.127	1.052	-	0.922	0.802	-	0.952	0.216
901	0.957	0.928	-	0.972	0.921	-	1.092	1.189	1.112	-	0.959	0.836	-	0.997	0.226
929	0.984	0.958	-	1.005	c/	-	1.134	c/	1.152	-	0.985	c/	-	1.036	0.235

Table VIIf. cont'd)

Time (h)	Sample code 505	511	517	523	535	547	605	611	617	623	629	635	647	Ave. CO_2 [a/]	DML (%) [b/]
949	0.998	0.980	–	1.024	–	–	1.157	–	1.178	–	1.011	–	–	1.058	0.240
1045	1.111	1.095	–	1.154	–	–	1.290	–	1.335	–	1.160	–	–	1.191	0.270
1114	1.165	1.161	–	1.234	–	–	1.409	–	1.462	–	1.295	–	–	1.288	0.292
1166	1.208	1.208	–	1.280	–	–	1.471	–	1.536	–	1.368	–	–	1.345	0.305
1313	1.281	1.302	–	1.408	–	–	1.934	–	1.867	–	1.785	–	–	1.596	0.362
1353	_c/	_c/	–	1.454	–	–	_c/	–	1.992	–	1.846	–	–	1.764	0.400
1402	–	–	–	1.596	–	–	–	–	2.140	–	1.953	–	–	1.896	0.430
1448	–	–	–	1.659	–	–	–	–	2.191	–	1.972	–	–	1.940	0.440
1497	–	–	–	1.724	–	–	–	–	2.241	–	1.989	–	–	1.985	0.450
1567	–	–	–	1.803	–	–	–	–	2.350	–	2.066	–	–	2.073	0.470
1615	–	–	–	1.842	–	–	–	–	2.419	–	2.103	–	–	2.117	0.481
1662	–	–	–	1.891	–	–	–	–	2.486	–	2.133	–	–	2.170	0.492

a/
Average weight of carbon dioxide (g) evolved from 300 g dry weight of the sample.

b/
Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using 1.47 g CO_2/g dry weight of the sample.

c/
Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIIg. Carbon Dioxide (Gram) Evolved by Medium Grain (Nato) Rough Rice During Storage at 23.9°C and 20.0% Moisture.

Time (h)	Sample code 301	307	313	325	337	343	419	Ave. CO_2 a/	DML (%) b/
47	0.029	0.080	0.059	0.038	0.095	0.020	0.099	0.060	0.016
97	0.064	0.142	0.112	0.067	0.171	0.039	0.181	0.111	0.030
117	0.071	0.165	0.136	0.073	0.200	0.043	0.209	0.128	0.035
163	0.093	0.226	0.190	0.097	0.272	0.055	0.277	0.173	0.047
236	0.143	0.362	0.314	0.178	0.421	0.111	0.452	0.283	0.077
264	0.160	0.396	0.345	0.198	0.460	0.121	0.534	0.316	0.086
289	0.171	0.423	0.367	0.213	0.482	0.124	0.591	0.338	0.092
357	0.200	0.515	0.447	0.261	0.597	0.152	0.684	0.401	0.110
403	0.240	0.592	0.514	0.312	0.684	0.183	0.763	0.470	0.128
453	0.310	0.709	0.592	0.404	0.815	0.250	0.819	0.555	0.151
479	0.359	0.592	0.644	0.548	0.875	0.279	0.874	0.595	0.162
499	–c/	0.709	0.675	–c/	0.916	0.294	0.912	0.701	0.191
597	–	0.765	0.881	–	1.171	0.437	1.084	0.867	0.232
643	–	0.805	0.960	–	1.273	0.466	1.143	0.929	0.253
695	–	1.059	1.048	–	1.385	0.487	1.251	1.044	0.284
740	–	1.152	1.109	–	1.464	0.507	1.327	1.110	0.302
787	–	1.264	1.202	–	1 587	0.537	1.480	1.213	0.330
835	–	–c/	1.283	–	1.709	0.562	–c/	1.185	0.322
882	–	–	1.405	–	1.851	0.601	–	1.286	0.350
960	–	–	1.624	–	1.992	0.708	–	1.442	0.392
1003	–	–	1.714	–	2.224	0.753	–	1.564	0.425

a/ Average weight of carbon dioxide (g) evolved from 250 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIIh. Carbon Dioxide (Gram) Evolved by Medium Grain (Nato) Rough Rice During Storage at 23.9°C and 18.2% Moisture.

Time (h)	Sample code 310	316	322	334	337	346	404	422	428	434	440	Ave. CO_2 a/	DML (%) b/
113	0.110	0.109	0.067	0.059	0.071	0.056	0.081	0.148	0.179	0.113	0.205	0.109	0.025
156	0.175	0.178	0.113	0.117	0.135	0.127	0.142	0.218	0.246	0.170	0.278	0.173	0.039
206	0.246	0.254	0.166	0.171	0.200	0.201	0.182	0.277	0.314	0.217	0.346	0.234	0.053
238	0.292	0.299	0.200	0.214	0.220	0.234	0.204	0.333	0.379	0.266	0.393	0.276	0.063
258	0.323	0.337	0.240	0.228	0.225	0.262	0.209	0.377	0.437	0.272	0.445	0.305	0.069
302	0.384	0.403	0.283	0.277	0.281	0.288	0.237	0.437	0.489	0.333	0.503	0.356	0.081
323	0.410	0.420	0.300	0.292	0.308	0.306	0.245	0.464	0.516	0.352	0.535	0.377	0.086
351	0.440	0.469	0.319	0.311	0.327	0.324	0.250	0.492	0.543	0.373	0.564	0.401	0.091
399	0.494	0.508	0.358	0.337	0.361	0.352	0.256	0.559	0.608	0.417	0.616	0.442	0.100
423	0.520	0.556	0.380	0.350	0.370	0.362	0.277	0.588	0.637	0.441	0.658	0.467	0.106
446	0.553	0.590	_c/	0.367	0.400	0.382	0.301	_c/	0.677	0.473	0.692	0.493	0.112
570	0.700	0.755	-	0.460	0.529	0.470	0.352	-	0.859	0.623	0.911	0.629	0.143
613	0.766	0.821	-	0.515	0.584	0.504	0.374	-	0.970	0.689	0.903	0.681	0.154
661	0.857	0.909	-	0.589	0.652	0.567	0.407	-	1.077	0.788	1.147	0.777	0.176
686	0.893	0.947	-	0.619	0.677	0.592	0.419	-	1.128	0.820	1.210	0.838	0.190
764	1.022	1.074	-	0.715	0.766	0.677	0.488	-	1.295	0.957	1.452	0.938	0.213
782	1.046	1.104	-	0.729	0.793	0.700	0.505	-	1.358	0.993	1.509	0.971	0.220
804	1.085	1.141	-	0.752	0.817	0.723	0.516	-	1.417	1.034	1.569	1.006	0.228
832	_c/	1.194	-	0.784	0.849	0.758	_c/	-	1.500	_c/	1.673	1.126	0.255
899	-	1.326	-	0.882	0.930	0.848	-	-	1.799	-	1.941	1.288	0.292
927	-	1.392	-	0.903	0.968	0.895	-	-	1.796	-	2.064	1.336	0.303
1030	-	1.607	-	1.101	1.136	1.064	-	-	2.127	-	2.182	1.536	0.348
1071	-	1.698	-	1.185	1.207	1.141	-	-	2.276	-	2.345	1.642	0.372
1096	-	1.756	-	1.232	_c/	_c/	-	-	2.350	-	_c/	1.782	0.404
1119	-	1.816	-	1.286	-	-	-	-	2.416	-	-	1.839	0.417
1163	-	1.878	-	1.340	-	-	-	-	2.501	-	-	1.906	0.432

a/ Average weight of carbon dioxide (g) evolved from 300 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2/g dry weight of the sample.

c/ Sample was taken for ergosterol and percentage discolored kernels measurements.

Table VIIi. Carbon Dioxide (Gram) Evolved by Medium Grain (Nato) Rough Rice During Storage at 23.9°C and 15.6% Moisture.

Time (h)	Sample code 305	311	317	323	341	347	411	417	435	447	Ave[a/]. CO_2	DML[b/] (%)
113	0.051	0.071	0.182	0.005	0.031	0.047	0.048	0.030	0.128	0.029	0.062	0.014
156	0.090	0.126	0.234	0.023	0.067	0.074	0.075	0.091	0.176	0.057	0.101	0.023
206	0.134	0.182	0.276	0.048	0.102	0.117	0.102	0.132	0.219	0.080	0.139	0.036
238	0.062	0.217	0.295	0.064	0.127	0.140	0.149	0.156	0.260	0.110	0.168	0.038
258	0.183	0.242	0.372	0.075	0.148	0.158	0.167	0.171	0.281	0.132	0.193	0.044
302	0.219	0.287	0.393	0.097	0.182	0.205	0.190	0.213	0.317	0.155	0.226	0.051
323	0.233	0.305	0.398	0.101	0.195	0.214	0.198	0.219	0.326	0.165	0.235	0.053
399	0.277	0.363	0.415	0.121	0.241	0.237	0.217	0.268	0.361	0.174	0.267	0.061
446	0.307	0.405	0.424	0.134	0.275	0.249	0.223	0.305	0.396	0.190	0.291	0.066
570	0.387	0.502	0.457	0.267	0.358	0.283	0.268	0.407	0.491	0.222	0.364	0.083
613	0.417	0.540	0.474	0.180	0.381	0.294	0.301	0.414	0.531	0.242	0.377	0.086
661	0.453	0.589	0.495	0.203	0.427	0.317	0.339	0.490	0.575	0.263	0.417	0.094
686	0.475	0.608	0.500	0.210	0.437	0.325	0.348	0.507	0.597	0.269	0.428	0.097
764	0.528	0.658	0.516	0.238	0.481	0.356	0.378	0.563	0.657	0.293	0.467	0.106
782	0.537	0.670	0.517	0.241	0.488	0.360	0.380	0.572	0.636	0.295	0.470	0.106
804	0.552	0.688	0.525	0.249	0.504	0.369	0.385	0.587	0.682	0.302	0.484	0.110
832	0.574	_c/	0.539	_c/	0.528	0.383	0.397	0.610	_c/	_c/	0.505	0.115
857	0.593	–	0.553	–	0.548	0.397	0.408	0.629	–	–	0.521	0.118
899	0.617	–	0.517	–	0.568	0.418	0.438	0.665	–	–	0.546	0.124
1030	0.706	–	0.647	–	0.665	0.468	0.518	0.764	–	–	0.623	0.142
1071	0.720	–	0.662	–	0.688	0.479	0.531	0.790	–	–	0.645	0.146
1096	0.734	–	0.670	–	0.703	0.485	0.539	0.804	–	–	0.656	0.149
1119	0.780	–	0.684	–	0.720	0.497	0.555	0.824	–	–	0.677	0.153
1163	0.863	–	0.711	–	0.753	0.517	0.581	0.856	–	–	0.714	0.162
1310	0.915	–	0.852	–	0.855	0.581	0.669	0.975	–	–	0.808	0.182
1351	0.931	–	0.879	–	0.873	0.595	0.684	0.993	–	–	0.827	0.187

(Table i. cont'd.)

Time (h)	Sample code 305	311	317	323	341	347	411	417	435	447	Ave[a/]. CO_2	DML[b/] (%)
1400	0.971	-	0.926	-	0.904	0.621	0.730	1.031	-	-	0.863	0.196
1446	1.022	-	0.976	-	0.946	0.662	0.781	1.065	-	-	0.909	0.206
1494	1.094	-	1.027	-	0.996	0.722	0.825	1.105	-	-	0.962	0.218
1575	1.135	-	1.070	-	1.038	0.759	0.859	1.169	-	-	1.005	0.228
1623	1.157	-	1.095	-	1.063	0.772	0.872	1.200	-	-	1.026	0.233
1680	1.174	-	1.114	-	1.083	0.780	0.889	1.214	-	-	1.042	0.236
1778	1.220	-	1.147	-	1.141	0.817	0.920	1.281	-	-	1.088	0.247
1823	1.258	-	1.174	-	1.186	0.860	0.950	1.347	-	-	1.129	0.256
1870	1.282	-	1.190	-	1.223	_c/	0.966	_c/	-	-	1.166	0.264
2014	1.314	-	1.227	-	1.282	-	0.990	-	-	-	1.203	0.273
2063	1.324	-	1.239	-	1.300	-	1.000	-	-	-	1.216	0.276
2100	1.347	-	1.253	-	1.317	-	1.011	-	-	-	1.232	0.279

a/ Average weight of carbon dioxide (g) evolved from 300 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide by using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIIj. Carbon Dioxide (Gram) Evolved by Medium Grain (Nato) Rough Rice During Storage at 18.3°C and 20.0% Moisture.

Time (h)	Sample code																
	101	107	113	119	125	131	137	143	201	207	213	219	225	231	240	246	Ave.[a/] CO_2	DML[b/] (%)
49	0.043	0.041	0.042	0.054	0.005	0.047	0.027	0.066	0.068	0.037	0.060	0.018	0.022	0.032	0.058	0.020	0.040	0.011
100	0.083	0.046	0.081	0.093	0.010	0.079	0.037	0.109	0.112	0.069	0.098	0.029	0.040	0.052	0.101	0.031	0.067	0.018
167	0.133	0.076	0.126	0.141	0.021	0.114	0.050	0.159	0.162	0.112	0.145	0.043	0.058	0.074	0.134	0.043	0.099	0.027
236	0.225	0.132	0.233	0.229	0.085	0.234	0.110	0.289	0.276	0.193	0.236	0.122	0.133	0.143	0.153	0.104	0.180	0.049
289	0.259	0.137	0.261	0.263	0.091	0.262	0.119	0.326	0.341	0.210	0.274	0.150	0.149	0.132	0.283	0.121	0.211	0.057
355	0.306	0.153	0.309	0.301	0.104	0.307	0.133	0.382	0.390	0.228	0.307	0.164	0.166	0.135	0.307	0.140	0.240	0.065
404	0.353	0.172	0.372	0.332	0.124	0.354	0.152	0.448	0.452	0.278	0.341	0.212	0.188	0.149	0.354	0.156	0.277	0.075
428	0.376	0.184	c/	0.346	0.135	0.380	0.163	c/	c/	c/	0.357	0.219	0.204	0.160	0.398	0.166	0.257	0.070
476	0.441	0.222	-	0.385	0.171	0.448	0.201	-	-	-	0.397	0.243	0.244	0.194	0.425	0.196	0.297	0.081
596	0.611	0.386	-	0.553	0.315	0.604	0.377	-	-	-	0.510	0.344	0.373	0.249	0.474	0.280	0.423	0.115
643	0.650	0.440	-	0.644	0.344	0.638	0.423	-	-	-	0.569	0.387	0.422	0.255	0.606	0.316	0.474	0.129
694	0.694	0.479	-	0.650	0.370	0.691	0.453	-	-	-	0.612	0.417	0.462	0.266	0.663	0.349	0.508	0.138
739	0.371	0.509	-	0.687	0.388	0.720	0.490	-	-	-	0.666	0.462	0.512	0.285	0.704	0.386	0.545	0.148
787	0.788	0.554	-	0.744	0.424	0.771	0.540	-	-	-	0.719	0.509	0.571	0.305	0.764	0.425	0.592	0.161
835	0.859	0.594	-	0.796	0.449	0.824	0.589	-	-	-	0.781	0.569	0.636	0.325	0.821	0.464	0.642	0.175
882	0.920	0.666	-	0.876	0.500	0.895	0.693	-	-	-	0.872	0.661	0.782	0.387	0.887	0.596	0.728	0.198
960	c/	0.763	-	0.971	c/	0.981	0.777	-	-	-	0.962	0.726	0.874	c/	c/	0.671	0.841	0.229
1002	-	0.806	-	1.016	-	1.007	0.826	-	-	-	0.992	0.754	0.903	-	-	0.705	0.876	0.238
1050	-	0.871	-	1.081	-	1.038	0.883	-	-	-	1.045	0.791	0.954	-	-	0.756	0.927	0.252
1103	-	0.939	-	1.141	-	1.064	0.920	-	-	-	1.094	0.820	0.996	-	-	0.797	0.971	0.264
1147	-	0.974	-	1.185	-	1.089	0.955	-	-	-	1.142	0.848	1.036	-	-	0.838	1.008	0.274
1195	-	1.068	-	1.274	-	1.121	1.025	-	-	-	1.198	0.886	1.084	-	-	0.885	1.068	0.291
1218	-	1.104	-	1.309	-	1.132	1.056	-	-	-	1.229	0.909	1.111	-	-	0.907	1.095	0.298
1315	-	1.251	-	c/	-	1.180	c/	-	-	-	c/	0.979	1.209	-	-	c/	1.155	0.314
1363	-	1.276	-	-	-	1.195	-	-	-	-	-	1.002	1.240	-	-	-	1.178	0.321
1411	-	1.313	-	-	-	1.220	-	-	-	-	-	1.207	1.273	-	-	-	1.208	0.328
1563	-	1.395	-	-	-	1.282	-	-	-	-	-	1.145	1.461	-	-	-	1.321	0.359
1603	-	1.406	-	-	-	1.298	-	-	-	-	-	1.150	1.469	-	-	-	1.331	0.362
1650	-	1.421	-	-	-	1.319	-	-	-	-	-	1.158	1.482	-	-	-	1.345	0.366
1698	-	1.437	-	-	-	1.347	-	-	-	-	-	1.167	1.497	-	-	-	1.362	0.371
1843	-	1.520	-	-	-	1.468	-	-	-	-	-	1.240	1.586	-	-	-	1.454	0.396
1891	-	1.576	-	-	-	1.516	-	-	-	-	-	1.255	1.620	-	-	-	1.492	0.406
2011	-	1.690	-	-	-	1.685	-	-	-	-	-	1.344	1.816	-	-	-	1.634	0.445
2060	-	1.715	-	-	-	1.734	-	-	-	-	-	1.365	1.882	-	-	-	1.674	0.456

a/ Average weight of carbon dioxide (g) evolved from 250 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2/g dry weight of the sample.

c/ Sample was taken out for ergosterol and discolored kernels measurements.

Table VIIk. Carbon Dioxide (Gram) Evolved by Medium Grain (Nato) Rough Rice During Storage at 18.3°C and 18.8% Moisture.

Time (h)	Sample code											Ave. CO_2 [a]	DML [b] (%)
	102	108	114	120	126	138	144	226	232	238	244		
49	0.029	0.012	0.022	0.015	0.017	0.028	0.020	0.022	0.030	0.024	0.024	0.022	0.006
100	0.042	0.020	0.035	0.020	0.021	0.042	0.027	0.039	0.042	0.039	0.039	0.039	0.011
167	0.055	0.021	0.044	0.024	0.029	0.059	0.035	0.053	0.058	0.054	0.055	0.044	0.013
236	0.099	0.052	0.085	0.058	0.069	0.101	0.079	0.117	0.121	0.155	0.110	0.087	0.024
289	0.110	0.056	0.102	0.058	0.077	0.121	0.085	0.127	0.127	0.159	0.134	0.095	0.026
355	0.139	0.076	0.126	0.081	0.107	0.154	0.114	0.147	0.147	0.184	0.187	0.128	0.035
404	0.171	0.097	0.155	0.104	0.129	0.184	0.141	0.165	0.171	0.212	0.209	0.144	0.039
428	0.185	0.106	0.168	0.110	0.139	0.198	0.151	0.175	0.182	0.227	0.221	0.155	0.042
476	0.223	0.133	0.201	0.135	0.167	0.235	0.186	0.231	0.239	0.297	0.269	0.194	0.053
596	0.296	0.190	0.278	0.204	0.233	0.318	0.256	0.343	0.315	0.384	0.355	0.269	0.073
643	0.310	0.200	0.295	0.225	0.251	0.334	0.290	0.360	0.343	0.412	0.374	0.290	0.079
694	0.335	0.218	0.317	0.259	0.280	0.359	0.294	0.375	0.360	0.441	0.394	0.306	0.083
739	0.357	0.227	0.331	0.279	0.298	0.371	0.308	0.385	0.373	0.460	0.406	0.319	0.087
787	0.377	0.250	0.360	0.314	0.333	0.406	0.337	0.407	0.395	0.500	0.433	0.347	0.094
835	0.397	0.265	0.388	0.336	0.360	0.421	0.357	0.421	0.412	0.520	0.450	0.365	0.099
882	0.430	0.308	0.424	0.402	0.426	c/	0.410	0.448	0.441	c/	0.481	0.411	0.112
960	0.489	0.369	0.485	0.513	0.531	-	0.486	0.513	0.513	-	0.539	0.482	0.131
1002	0.514	0.396	0.526	0.501	0.582	-	0.523	0.533	0.539	-	0.564	0.511	0.139
1050	0.547	0.433	0.576	0.615	0.644	-	0.577	0.567	0.579	-	0.601	0.560	0.152
1103	0.583	0.477	0.614	0.689	0.706	-	0.630	0.592	0.611	-	0.635	0.606	0.165
1147	0.620	0.519	0.643	0.760	0.759	-	0.682	0.650	0.684	-	0.672	0.652	0.177
1195	0.671	0.562	0.692	0.844	0.836	-	0.744	0.686	0.730	-	0.718	0.706	0.192
1218	0.696	0.596	0.714	0.891	c/	-	0.784	0.706	0.763	-	0.743	0.737	0.200
1315	0.828	0.725	0.843	c/	-	-	0.908	0.779	0.842	-	0.841	0.821	0.223
1363	0.854	0.799	0.879	-	-	-	0.953	0.801	0.869	-	0.872	0.861	0.234

(Table k. cont'd)

Time (h)	Sample code											Ave. CO_2 [a/]	DML (%) [b/]
	102	108	114	120	126	138	144	226	232	238	244		
1411	0.899	0.878	0.911	-	-	-	0.999	0.826	0.918	-	0.903	0.906	0.247
1563	1.090	1.508	1.272	-	-	-	1.686	0.974	1.266	-	1.087	1.257	0.342
1603	1.119	_c/	1.292	-	-	-	_c/	_c/	1.307	-	1.109	1.207	0.328
1650	1.150	-	1.328	-	-	-	-	-	1.346	-	1.136	1.240	0.337
1698	1.184	-	1.350	-	-	-	-	-	1.404	-	1.165	1.276	0.347
1843	1.295	-	2.662	-	-	-	-	-	1.482	-	1.262	1.676	0.456
1891	1.382	-	2.724	-	-	-	-	-	1.684	-	1.342	1.783	0.485
2011	1.498	-	2.928	-	-	-	-	-	1.880	-	1.449	1.939	0.528
2060	1.528	-	2.996	-	-	-	-	-	1.957	-	1.486	1.992	0.542

a/
Average weight of carbon dioxide (g) evolved from 250 g dry weight of the sample.

b/
Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/
Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIII. Carbon Dioxide (Gram) Evolved by Medium Grain (Nato) Rough Rice During Storage at 18.3°C and 17.5% Moisture.

Time (h)	Sample code 117	129	135	141	147	205	211	217	223	229	235	241	Ave. CO_2 [a/]	DML (%) [b/]
113	0.032	0.035	0.055	0.027	0.028	0.030	0.046	0.044	0.086	0.118	0.004	0.074	0.048	0.011
156	0.047	0.060	0.050	0.050	0.051	0.028	0.049	0.052	0.112	0.141	0.008	0.097	0.062	0.014
206	0.071	0.091	0.098	0.082	0.084	0.040	0.066	0.067	0.141	0.173	0.017	0.127	0.088	0.020
252	0.086	0.104	0.115	0.101	0.106	0.037	0.067	0.071	0.158	0.197	0.027	0.147	0.101	0.023
300	0.126	0.154	0.168	0.153	0.160	0.064	0.097	0.104	0.208	0.251	0.062	0.198	0.146	0.033
348	0.138	0.175	0.179	0.176	0.181	0.066	0.100	0.107	0.228	0.273	0.060	0.220	0.159	0.036
398	0.147	0.195	0.188	0.197	0.203	0.067	0.105	0.109	0.249	0.194	0.064	0.243	0.172	0.039
445	0.161	0.220	0.204	0.224	0.221	0.074	0.116	0.118	0.276	0.322	0.066	0.271	0.190	0.043
567	0.199	0.278	0.247	0.293	0.303	0.096	0.131	0.144	0.345	0.399	0.083	0.336	0.238	0.054
609	0.219	0.308	0.270	0.324	0.344	0.108	0.138	0.161	0.366	0.431	0.098	0.365	0.260	0.059
659	0.247	0.340	0.304	0.362	0.375	0.132	0.158	0.176	0.403	0.470	0.117	0.404	0.291	0.066
761	0.282	0.390	0.346	0.417	0.436	0.199	0.180	0.208	0.440	0.527	0.140	0.458	0.335	0.076
829	0.353	0.478	0.433	0.503	0.530	0.258	0.239	0.276	0.528	0.625	0.199	0.550	0.415	0.094
895	0.378	0.507	0.463	0.536	0.562	0.273	0.256	0.299	0.554	0.663	0.216	0.586	0.411	0.100
921	0.400	0.532	0.490	0.563	0.585	0.285	0.271	0.317	0.575	0.692	0.231	0.613	0.463	0.105
1039	c/	0.606	c/	0.651	0.676	0.326	0.311	0.381	0.653	c/	c/	0.699	0.538	0.122
1086	-	0.629	-	0.678	0.703	0.340	0.322	0.404	0.668	-	-	0.727	0.560	0.127
1135	-	0.663	-	0.719	0.744	0.367	0.345	0.442	0.714	-	-	0.768	0.595	0.135
1157	-	0.680	-	0.736	0.762	0.383	0.355	0.472	0.729	-	-	0.785	0.613	0.139
1306	-	0.776	-	0.843	0.877	0.478	0.407	0.614	0.830	-	-	0.890	0.714	0.162
1346	-	0.809	-	0.877	0.910	0.513	0.435	0.661	0.863	-	-	0.926	0.750	0.170
1395	-	0.860	-	0.926	0.950	0.551	0.472	0.711	0.907	-	-	0.974	0.794	0.180
1441	-	0.934	-	0.995	1.025	0.600	0.523	0.776	0.960	-	-	1.033	0.856	0.194
1490	-	0.964	-	1.084	1.101	0.673	0.597	0.865	1.026	-	-	1.101	0.926	0.210
1514	-	0.989	-	1.120	1.119	0.693	0.609	0.900	1.050	-	-	1.106	0.948	0.215
1561	-	1.032	-	1.164	1.160	0.719	0.634	0.940	1.093	-	-	1.194	0.992	0.225
1608	-	1.104	-	1.239	1.233	1.775	0.694	1.013	1.167	-	-	1.276	1.063	0.241
1656	-	1.225	-	c/	1.356	0.875	0.798	1.128	1.285	-	-	c/	1.111	0.252

(Table VIII cont'd)

Time (h)	Sample code 117	129	135	141	147	205	211	217	223	229	235	241	Ave. CO_2 [a]	DML (%) [b]
1754	-	1.284	-	-	1.352	0.863	0.786	1.139	1.297	-	-	-	1.120	0.254
1799	-	1.299	-	-	1.409	0.907	0.829	1.204	1.335	-	-	-	1.164	0.264
1864	-	1.369	-	-	1.477	0.949	0.886	1.277	1.371	-	-	-	1.222	0.277
1990	-	1.410	-	-	1.498	0.954	0.909	1.338	1.405	-	-	-	1.252	0.284
2049	-	1.441	-	-	1.525	0.963	0.921	1.351	1.419	-	-	-	1.270	0.288
2096	-	1.481	-	-	1.551	0.974	0.936	1.375	1.437	-	-	-	1.292	0.293

a/
Average weight of carbon dioxide (g) evolved from 300 g dry weight of the sample.

b/
Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/
Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIIIa. Carbon Dioxide (Gram) Evolved by Hand-threshed Long Grain (Arkansas 007) Rough Rice During Storage at 20.0% Moisture and 35°C.

Time (h)	Sample code 804	807	819	822	825	828	831	834	837	840	843	846	Ave. CO_2 [a]	DML (%) [b]
35	0.304	0.217	0.379	0.042	0.028	0.152	0.298	0.220	0.281	0.240	0.147	0.314	0.188	0.051
57	0.450	0.394	0.562	0.074	0.045	0.313	0.444	0.401	0.423	0.337	0.222	0.476	0.280	0.076
105	0.813	0.712	0.884	0.111	0.064	0.476	0.772	0.714	0.625	0.584	0.389	0.711	0.525	0.143
131	c/	1.016	c/	0.368	0.312	0.569	c/	1.002	0.921	0.918	0.613	0.982	0.745	0.203
153	-	1.195	-	0.596	0.594	0.640	-	1.148	1.080	1.083	0.675	1.282	0.923	0.251
237	-	1.862	-	1.550	1.606	0.837	-	1.641	1.790	1.711	0.897	1.942	1.537	0.418
250	-	1.956	-	1.618	1.775	0.871	-	1.732	1.961	1.807	0.910	2.048	1.631	0.444
273	-	c/	-	2.108	2.035	c/	-	1.841	2.167	1.975	0.960	c/	1.848	0.503
297	-	-	-	2.349	2.297	-	-	1.996	2.387	2.179	1.026	-	2.039	0.555
321	-	-	-	2.414	c/	-	-	2.084	c/	2.269	c/	-	2.256	0.614
346	-	-	-	2.692	-	-	-	2.270	-	2.487	-	-	2.483	0.676

a/ Average weight of carbon dioxide (g) evolved from 250 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIIIb. Carbon Dioxide (Gram) Evolved by Hand-threshed Long Grain (Arkansas 007) Rough Rice During Storage at 16.8% Moisture and 35^{o}C.

Time	Sample code								Ave.[a]	DML[b]
(h)	701	704	713	719	722	731	734	743	CO_2	(%)
27	0.170	0.165	0.177	0.195	0.122	0.188	0.108	0.101	0.153	0.042
92	0.487	0.442	0.519	0.567	0.333	0.475	0.391	0.384	0.450	0.122
118	0.612	0.682	0.617	0.687	0.408	0.619	0.560	0.507	0.587	0.160
141	0.719	0.801	0.723	c/	0.462	0.844	0.593	c/	0.691	0.168
224	1.115	1.130	1.091	-	0.663	1.309	0.991	-	1.049	0.246
237	1.184	1.205	1.154	-	0.704	1.389	0.994	-	1.105	0.300
261	1.316	1.330	1.265	-	0.796	c/	c/	-	1.176	0.320
285	1.443	1.459	1.381	-	0.876	-	-	-	1.314	0.358
309	1.569	1.519	1.501	-	0.912	-	-	-	1.375	0.374
333	1.700	c/	1.621	-	c/	-	-	-	1.661	0.452

a/ Average weight of carbon dioxide (g) evolved from 250 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergolsterol and percentage discolored kernels measurements.

Table VIIIc. Carbon Dioxide (Gram) Evolved by Hand-threshed Long Grain (Arkansas 007) Rough Rice During Storage at 15.4% Moisture and 35^{o}C.

Time	Sample code										Ave. CO_2 [a]	DML (%) [b]
(h)	601	604	607	616	619	622	631	643	643	646		
26	0.043	0.019	0.031	0.036	0.031	0.048	0.038	0.048	0.015	0.045	0.033	0.009
91	0.086	0.052	0.067	0.115	0.100	0.136	0.124	0.118	0.034	0.105	0.094	0.026
259	0.166	0.114	0.157	0.264	0.234	0.312	0.318	0.279	0.103	.0247	0.219	0.059
307	0.211	0.136	0.199	0.314	0.293	0.386	0.380	.0342	0.123	0.307	0.269	0.073
356	0.271	0.170	0.250	0.379	0.343	0.454	0.445	0.412	0.131	0.380	0.324	0.088
403	0.333	0.192	0.294	0.446	0.431	0.531	0.517	0.487	0.161	0.458	0.385	0.105
507	0.635	0.337	0.497	0.762	0.669	0.899	0.865	0.759	0.267	0.737	0.642	0.175
523	c/	0.381	0.564	0.830	c/	1.006	c/	0.866	0.312	0.838	0.685	0.186
622	-	-	1.150	1.523	-	1.884	-	1.598	0.891	1.602	1.441	0.392

a/ Average weight of carbon dioxide (g) evolved from 250 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table VIIId. Carbon Dioxide (Gram) Evolved by Hand-threshed Long Grain (Arkansas 007) Rough Rice During Storage at 19.7% Moisture and 23.9°C.

Time	Sample code								Ave.[a]	DML[b]
(h)	510	513	513	522	528	534	537	543	CO_2	(%)
34	0.068	0.062	0.076	0.068	0.070	0.063	0.075	0.076	0.070	0.019
58	0.138	0.128	0.148	0.098	0.143	0.121	0.140	0.143	0.132	0.036
105	0.277	0.229	0.284	0.203	0.287	0.287	0.368	0.270	0.276	0.075
131	0.344	0.248	0.340	0.238	0.348	0.315	0.317	0.326	0.309	0.084
153	0.438	0.331	0.442	0.315	0.450	0.416	0.420	0.424	0.404	0.110
238	c/	0.536	c/	0.525	0.736	0.688	0.707	0.667	0.643	0.175
251	-	0.568	-	0.570	0.784	0.733	0.732	0.694	0.680	0.185
273	-	0.632	-	0.657	0.852	0.825	0.838	0.758	0.761	0.207
298	-	0.687	-	0.738	0.956	0.914	0.929	0.849	0.845	0.230
322	-	0.733	-	0.776	0.993	0.989	0.970	0.921	0.897	0.244
347	-	0.788	-	0.834	c/	1.075	c/	1.009	0.926	0.252
371	-	0.839	-	0.873	-	1.160	-	1.084	0.988	0.269
396	-	0.891	-	0.944	-	1.244	-	1.155	1.058	0.288
418	-	0.918	-	1.008	-	1.315	-	1.228	1.117	0.304
522	-	1.046	-	1.289	-	1.608	-	1.554	1.374	0.374

a/ Average weight of carbon dioxide (g) evolved from 250 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average carbon dioxide using the factor of 1.47 g CO_2 /g dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measirements.

Table IXa. Carbon Dioxide (Gram) Evolved by Mechanically-Threshed Long Grain (Arkansas 007) Rough Rice During Storage at 35°C and 19.8% Moisture.

Time (h)	Sample code 805	811	814	817	820	829	832	835	838	844	Ave. CO_2 [a]	DML (%) [b]
35	0.435	0.594	0.409	0.599	0.632	0.206	0.555	0.144	0.369	0.436	0.441	0.120
57	0.744	0.912	0.728	0.916	0.970	0.539	0.855	0.283	0.669	0.770	0.739	0.201
105	1.472	1.011	1.495	1.007	1.771	1.293	1.585	0.660	1.421	1.538	1.325	0.361
131	1.832	c/	c/	1.888	c/	c/	c/	c/	1.807	1.943	1.843	0.508
153	2.133	-	-	2.121	-	-	-	-	2.173	2.141	2.142	0.583
237	3.544	-	-	c/	-	-	-	-	3.658	c/	3.602	0.980
250	3.749	-	-	-	-	-	-	-	3.750	-	3.750	1.020

a/ Average weight of carbon dioxide (g) evolved from 250 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table IXb. Carbon Dioxide (Gram) Evolved by Mechanically-Threshed Long Grain (Arkansas 007) Rough Rice During Storage at 35.0^{o}C and 17.1% Moisture.

Time (h)	Sample code 702	705	711	714	717	720	726	747	Ave. CO_2 [a/]	DML (%) [b/]
27	0.142	0.139	0.075	0.131	0.141	0.137	0.107	0.111	0.123	0.033
92	0.455	0.435	0.310	0.393	0.445	0.334	0.328	0.398	0.388	0.106
118	0.583	0.555	0.393	0.492	0.568	0.557	0.422	0.515	0.511	0.139
141	0.694	0.656	0.459	0.572	0.671	0.667	0.479	0.595	0.599	0.163
224	1.167	1.082	c/	c/	1.097	1.094	0.683	0.937	1.010	0.275
237	1.244	1.157	-	-	1.179	1.177	0.734	1.025	1.086	0.296
261	1.396	c/	-	-	1.329	1.340	0.836	c/	1.225	0.333
285	1.581	-	-	-	1.493	1.530	0.929	-	1.383	0.376
309	1.794	-	-	-	1.560	1.741	1.075	-	1.543	0.420
333	2.035	-	-	-	c/	2.002	c/	-	2.019	0.549

a/ Average weight of carbon dioxied (g) evolved from 250 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table IXc. Carbon Dioxide (Gram) Evolved by Mechanically-Threshed Long Grain (Arkansas 007) Rough Rice During Storage at 35.0°C and 17.1% Moisture.

Time (h)	Sample code 602	608	611	614	620	626	629	632	635	638	Ave. CO_2 [a]	DML (%) [b]
26	0.013	0.024	0.026	0.028	0.034	0.026	0.018	0.018	0.021	0.014	0.023	0.006
91	0.040	0.067	0.053	0.057	0.092	0.068	0.049	0.044	0.048	0.018	0.054	0.015
259	0.086	0.136	0.107	0.133	0.247	0.195	0.122	0.127	0.119	0.042	0.131	0.036
307	0.123	0.178	0.147	0.188	0.313	0.252	0.168	0.170	0.157	0.061	0.176	0.048
356	0.166	0.211	0.203	0.256	0.386	0.322	0.233	0.232	0.214	0.095	0.232	0.063
403	0.205	0.259	0.248	0.328	0.462	0.384	0.283	0.276	0.257	0.109	0.282	0.077
507	0.337	0.511	0.375	0.576	0.651	0.556	0.452	0.363	0.397	0.204	0.442	0.115
523	_c/	0.577	_c/	0.608	0.697	.0609	0.477	0.391	0.426	0.213	0.500	0.136
622	-	_c/	-	0.781	0.892	0.873	0.619	0.528	0.577	0.243	0.645	0.176

a/ Average weight of carbon dioxide (g) evolved from 250 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

Table IXd. Carbon Dioxide (Gram) Evolved by Mechanically-Threshed Long Grain (Arkansas 007) Rough Rice During Storage at 23.9°C and 19.8% Moisture.

Time (h)	Sample code 508	511	514	517	520	526	529	532	535	547	Ave. CO_2 [a/]	DML (%) [b/]
34	0.296	0.207	0.336	0.247	0.267	0.292	0.301	0.230	0.216	0.253	0.265	0.072
58	0.439	0.362	0.478	0.441	0.431	0.375	0.460	0.392	0.368	0.367	0.411	0.112
105	0.746	0.665	0.731	0.708	0.741	0.724	0.599	0.682	0.694	0.581	0.687	0.187
131	0.991	0.876	0.914	0.919	1.022	c/	c/	0.989	0.871	0.738	0.915	0.249
153	c/	1.028	1.021	1.043	1.214	-	-	1.176	0.955	c/	1.073	0.292
238	-	1.755	1.543	1.186	2.438	-	-	2.022	1.597	-	1.757	0.478
251	-	1.876	1.640	1.313	2.266	-	-	2.206	1.771	-	1.885	0.502
273	-	2.018	c/	c/	2.453	-	-	2.397	1.924	-	2.198	0.598
298	-	2.148	-	-	2.743	-	-	2.725	2.161	-	2.444	0.665
321	-	2.165	-	-	2.780	-	-	2.750	2.184	-	2.470	0.672

a/ Average weight of carbon dioxide (g) evolved from 250 g dry weight of the sample.

b/ Equivalent dry matter loss (%), calculated from the average weight of carbon dioxide using the factor of 1.47 g CO_2 per gram dry weight of the sample.

c/ Sample was taken out for ergosterol and percentage discolored kernels measurements.

QUALITY INDICATORS FOR ROUGH RICE DURING AERATED STORAGE

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submitted in partial fulfillment of the

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1985

ABSTRACT

A method for quantitating ergosterol in wheat, maize and rice was developed using thin layer chromatography (TLC) and ultraviolet (UV) spectroscopy. The concentration of ergosterol has been proposed by others as a measure of fungal invasion in grain; ergosterol is a metabolite of fungi but not of plants. TLC was used to purify the sterol fraction of the non-saponifiable lipids extracted from grain, while UV spectroscopy was used to quantitate the concentration of ergosterol. Recovery of ergosterol from spiked grain samples was 84-98% for rough rice and 91-102% for corn. Delaying the extraction of the sterol band from the TLC plate for 2 h gave reduced recovery. The TLC-UV method has a repeatability of $\pm$0.49 ug/g with obtained ergosterol values in closed agreement with quantitation by high performance liquid chromatography (HPLC).

Storage studies were done on small samples of rough rice to develop a mathematical model for predicting safe holding or drying time for high moisture rough rice. Long-grain (Newrex and Arkansas 007) and medium-grain (Nato) rough rice were stored in aerated jars at moisture levels between 15.7 and 20% and temperatures at 35^{o}, 29.4^{o}, 23.9^{o} and 18.3^{o}C. Mechanical damage levels were 5.3 and 1.6% for the mechanically- and hand-threshed Arkansas 007 rice respectively. Carbon dioxide-free air, which was humidified to maintain moisture levels was passed slowly through the stored rice. Carbon dioxide (CO_2) generated by the respiring grain and mold was monitored with time, along with ergosterol and percent damaged kernels.

A mathematical equation was derived to relate dry matter loss (DML) from rough rice with moisture, temperature, storage time and mechanical

damage. The constants in the equation were found to vary with different rice varieties.

The ergosterol level in stored rough rice was also expressed in an equation as a function of moisture, temperature, and storage time. The ergosterol level in stored rice was a more accurate measure of fungal invasion than DML. It is proposed that ergosterol concentration in grain replace DML in computer simulations of drying and holding of grain.

In rough rice stored at a moisture between 15.6-20%, the increase in the number of the damaged kernels correlated well (r=0.96) with the increase in ergosterol level. Using the current limits on damaged kernels in U.S. grading standard, an increase in ergosterol content of >1 ug/g from its initial value would indicate that rice dropped below U.S. No. 2 grade.

DML correlated poorly with the damaged kernels (r=0.62-0.63), except in hand-threshed Arkansas 007 rice. At high moisture, the percent damaged kernels increased disproportionately more than DML. Thus, DML cannot distinguish U.S. grades of rice as determined by damaged kernels.